NASA CR-134350

DEVELOPMENT OF A LONG WAVELENGTH SPECTROMETER FOR THE 24-CHANNEL MULTISPECTRAL SCANNER

INSTRUCTIONS FOR INSTALLATION, START-UP, AND ADJUSTMENT

Prepared For

NASA LYNDON B. JOHNSON SPACE CENTER
TECHNICAL SUPPORT PROCUREMENT BRANCH
HOUSTON, TEXAS 77058

Contract No. NAS 9-13189
Amendment No. 1 S

Report No. 5064 30 May 1974

AEROJET ELECTROSYSTEMS COMPANY

AZUSA, CALIFORNIA

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A DIVISION OF AEROJET GENERAL
1100 WEST HOLLYVALE STREET, AZUSA, CALIFORNIA 91702

TABLE OF CONTENTS

Section		Page
1	INTRODUCTION	1
2	DESIGN DESCRIPTION	1
3	MECHANICAL AND ELECTRICAL CONNECTIONS	4
3.1	Array Electrical Connections	4
3.2	Cooler Connections	5
3.3	Cooler Electrical Connections	5
4	SYSTEM START-UP	6
5	ADJUSTMENTS AND CALIBRATIONS	7
5.1	Temperature Indicator Meter Calibration	7
5.2	Detector/Array Checkout and Bias Adjustment, Array 4	8
5.3	Detector/Array Checkout and Bias Adjustment, Array 3	11
5.4	Gain Adjustments	12
6	DEWAR VACUUM	14
6.1	Reestablishing System Vacuum	15
6.2	Vacuum Valve Operation	16
6.3	Ion Pump	16
Appendix A	Cooler Performance Data	A-1
Appendix B	Drawing List	B-1
Appendix C	Acceptance Test Procedure	C-1

FIGURES

Figure 1 Array 3 Detector Diode Curves 13

Figure 2 VacIon Pump Current vs Pressure 18

TABLE

Table 1 Array 4 Signal and Noise Variation with Temperature 9

REFERENCES

Reference Number	Title
1	LWS Design Replacement Study, AESC Report No. 4713 dated 23 February 1973
2	Installation Drawing, LWS Arrays 3 and 4, 1301021
3	Interconnect, LWS 3 (InSb) System, 1308785
4	Interconnect, LWS 4 (Ge:Hg) System, 1308784
5	Instructions for the Installation, Start-up, and Basic Trouble-shooting Procedures for the Model 0120 IR Refrigerator, Cryognic Technology Inc., April 1968
6	Schematic, LWS 3 & 4 Temperature Control, 1308781
7	Schematic, LWS 3 & 4 Power Supply, 1308780
8	Schematic Diagram, LWS 4 Focal Plane, 1301037
9	Schematic, LWS 4 (Ge:Hg) Preamp, 1308782
10	Schematic, LWS 3 (InSb) Preamp, 1308783
11	Instructions for 3/4-Inch All Metal Mini-Valve 951-5014, Varian Vacuum Division 87-400 264, July 1970

1. INTRODUCTION

This instruction manual provides the basic information required for start-up and operation of two long-wavelength focal-plane and cooler assemblies, including the amplifiers and temperature control systems. The focal plane systems, referred to as the Long Wavelength Spectrometer (LWS) were developed under NASA contract NAS 9-13189 Amendment No. 1 S for direct replacement of Arrays 3 and 4 into the multispectral scanner presently being operated by the NASA Manned Spacecraft Center Facility and Laboratory Support Branch.

The equipment furnished under this contract is comprised of two major sub-assemblies: Array 3 with three Indium Antimonide detector channels and Array 4 with seven Mercury doped Germanium detector channels. Each array is mounted on a government furnished cryogenic cooler (Cryogenic Technology Inc. Model 120 with Aerojet designed cold stations) and includes the vacuum housings, mounting hardware (x, y, z translation and rotation stages) and detector signal conditioning, temperature control and monitoring electronics. The two arrays have been designed to operate independently and do not share common equipment (viz power supplies, housings, mounts, etc.). Thus, either Array may be removed from the MSS for test, adjustment, calibration, etc., without interrupting the service of the remaining Array.

The two long-wavelength arrays cover the spectral region from 2.1 to 13.0 micrometers. Array 3 provides three channels operating in the 2.1 to 4.75 micrometer region and Array 4 provides seven channels operating in the 6.0 to 13.0 micrometer region.

2. DESIGN DESCRIPTION

During the LWS Design Replacement Study portion of the contract, design criteria were established for the final design as follows:

- Minimal microphonic noise

- o Stable detector performance, detectivity (D^*), etc.
- o Stable frequency response due to split preamplifier (buffer stage operating at cryogenic temperatures)
- o Cooler replacement/servicing without having to break Dewar vacuum, or disturbing focal plane alignment
- o Increased MTBF (in contrast to present units employed in MSS)
- o Commonality and interchangeability of Array 4 detector assembly (present detectors and heat sink interchangeable with proposed design)
- o Commonality of cooler components between the two arrays and with other cooler assemblies presently in use at MSC

The replacement arrays achieve the above goals.

Minimal noise has been achieved by including a source follower preamplifier stage on the cooled focal plane of Array 4 ($28^{\circ}K$). Thus, the source-follower junction is physically close to the detector minimizing the effects of capacitive loading due to cable length as well as microphonic and random noise effects. Cabling within the dewar is accomplished with separate tape cables for signal (with buffer amplifier connections) and for the temperature control (power and sensing) which further minimizes microphonic and electrical pick-up. In order to retain detector noise limited performance with Array 3, it is not practical to use a cooled buffer amplifier, nor is it necessary. The high capacitance of the InSb detectors (800 to 1400 pf) limits the significance of cable capacitance. However the design employs cooled load resistors for reduction of Johnson noise and tape cable connections similar to those installed in Array 4.

Stable detector performance was achieved for the InSb detectors of Array 3 through development of a unique mounting technique. The detectors have been temperature cycled repeatedly over a three month period with no observed performance degradation. The mercury-doped germanium detectors of Array 4 have also been extensively operated and tested with no observable change in their characteristics.

The capacity of the CTI Model 120* coolers exceeds the system requirements. Cool-down time for both Arrays is approximately one hour and the lowest attainable temperature is approximately 10° below the nominal operating temperature thus assuring adequate cooling capacity under adverse conditions. The predicted "thermal chugging" did occur with the Array 4 system, but was reduced to an insignificant level by using a thermal capacitance shim between the cold station and the focal plane assembly. This phenomena is discussed in the Final Report for the study phase of the program (Reference 1). As also discussed in the study report, the Array 3 cooler was supplied with a dummy second stage due to the reduced cooling requirements for the InSb detectors. (60 to 80°K). This single stage provides ample capacity and does not require significant focal plane heating to maintain optimal temperature. Performance data for the coolers is included in Appendix A.

The heat sink, filters and detectors of Array 4 are interchangeable with the corresponding components of the present Array 4. As a continuation of the development, these items will be incorporated in a spare array presently being manufactured.

During development of the Arrays and auxiliary equipment, ease of installation, adjustment and maintenance were considered to be of prime importance. Accordingly, the translational and rotational mounting stages provide more than 1/4" adjustment in all three axes and more than 10° in rotation. This facility for adjustment will simplify installation and align-

---

*Manufactured by Cryogenics Technology Incorporated, Waltham, Mass.

ment in the MSS. An Installation Drawing (1301020, Reference 2) has been included in the drawing package illustrating the calculated location for installation of the arrays into the MSS. Connection of 400 Hz power to the two electronics units and output of the amplifiers to the MSS signal processing equipment will complete the installation.

Instructions for accomplishing the various electrical adjustments for the system are included in the following sections of this manual. However, it is not expected that these adjustments will be required unless a component replacement necessitates repeat of the test and calibration. All necessary adjustments were made prior to acceptance testing and the user is encouraged to operate the equipment as received.

Performance data for the two arrays was recorded during the Acceptance Test on 13 May 1974. The Acceptance Test Procedure (AE-23233A) with the recorded data is included as Appendix C to this manual. Discussions of the test rationale, methods and test results are included in this section.

3. MECHANICAL AND ELECTRICAL CONNECTIONS

3.1 Array Electrical Connections

Connect the electrical cables to their respective arrays and electronics units in accordance with interconnect drawings 1308785, Array 3 and 1308784, Array 4, (Reference 3 and 4). Although it is possible to connect the cables to the incorrect array or electronics unit, no damage will result. However, the equipment will not function properly. Each cable is identified with respect to function and array by a nylon tie. Also, the connector functions have been labeled on the electronics units. The power cables are interchangeable and, in addition, may be connected to either a single phase 115 volt 60 Hz or 400 Hz supply or to a 208 volt source of either frequency. Refer to the interconnect drawings for connector pin letter required for the selected voltage. The power cables were shipped with the mating connector for the electronics unit only.

3.2 Cooler Connections

Install flexible hoses between the CTI Model 0120 helium compressor and the array refrigerators. The GAS SUPPLY connects to the yellow connection on the refrigerator and the GAS RETURN connects to the body fitting on the refrigerator. After connection, verify that the refrigeration system pressure is 225 psi as indicated on the supply pressure gauges located on the compressor assembly panel. If the system pressure is low and requires additional helium, refer to the CTI Instructions for the Model 0120 IR Refrigerator dated April 1968 (Reference 5). This manual has been included with the documentation package.

3.3 Cooler Electrical Connections

Connect wiring harnesses between the helium compressor and the Arrays. The cables provided were prepared for laboratory testing only and are not considered part of the deliverable hardware. When preparing new cables, note that the phase designations at the refrigerator connection are Phase A to pin C, Phase B to Pin B and Phase C to Pin A. (Refer to Figure 7 of the CTI Instructions for the wiring diagram.) If these phase connections are improperly made, the refrigerator assemblies and detector arrays will be severely damaged. Also, when connecting the compressor to the 208V, 3Ø, 400 Hz source, verify that the phase connections are correct. The compressor has a phase sensitive relay incorporated and incorrect phase sequence will prevent compressor start-up. However, correct rotation should be verified after start-up by checking that the air flow from the compressor fan is directed across the heat exchanger and the hermetically sealed compressor assembly. The start relay for the cooler system is powered from a 28VDC source connected to the orange and black wires of the test harness.

> CAUTION: The orange wire must be connected to the positive 28V source and the black to the negative. A diode across the start relay coil will be destroyed if the correct polarity is not applied.

4. SYSTEM START-UP

The cooler system may now be started. Cool down to operating temperature for both units requires 40 to 60 minutes. During the cool down period power should not be applied to the electronics units and the arrays. It is not expected that damage would occur if power were applied to the arrays during cool down, but the refrigerator heat load would be increased, thus retarding the cool down. Also, a random failure in the temperature control electronics would not damage the focal plane. After approximately 40 minutes, apply power to the electronics units and observe the temperature indication and control meters. The control setting on Array 3 has been set to $60^{\circ}K$ and to $28^{\circ}K$ on Array 4. Normally, the temperature will overshoot the set point by several degrees when the temperature control system is first turned on or when the system is initially cooling down. The temperature will stabilize within approximately 1 minute after the first overshoot and the arrays can then be operated. The temperature control set points and indicator meter calibration were adjusted prior to shipment, further adjustment should not be necessary. If these functions require resetting, the following paragraphs describe the procedures.

5. ADJUSTMENTS AND CALIBRATIONS

5.1 Temperature Indicator Meter Calibration

a. Determine the monitor thermistor resistance at the nominal operating temperature. (225 ohms, Array 3; 2300 ohms, Array 4). These resistances are determined from the thermistor calibration curves included in the Acceptance Test Procedure, Appendix C.

b. Connect a resistance of the value determined in (a) above to pins "c" and "d" of the temperature control connector on the electronics unit. (See interconnect drawings 1308784 and 1308785, Reference 3 and 4.)

c. Adjust trim potentiometer R18 (drawing 1308781, Reference 6) such that the temperature indicator meter reads the value selected in (a) above. The R18 potentiometer is located on the temperature control card furthest from the large output transistor. Remove the calibration resistor and reconnect the temperature control cables.

d. Adjust trim potentiometer R3 (located nearest to the large output transistor) to the desired operating temperature (nominally 60°K for Array 3 and 28°K for Array 4) by making small adjustments to the potentiometer and observing the temperature indication meter. Allow sufficient time for the system to establish control while making the temperature adjustments. It is important to note that temperature changes of as little as 1 or 2 degrees will significantly affect the performance of the mercury doped germanium detectors of Array 4. The optimal 28°K operating point for this array was established after extensive testing and represents the best compromise temperature which is suitable for all seven channels. Since the bias voltage also changes with temperature, it is important that the optimal temperature be maintained and that bias voltages are checked occasionally to assure the best detector performance. During final system checkout, tests of signal to noise were made for several operating temperatures without readjustment of the bias. Data from these tests is submitted in Table 1 to illustrate the effect of minor temperature changes.

5.2 Detector/Array Checkout and Bias Adjustment, Array 4

CAUTION

Never remove or replace amplifier cards or connect and disconnect the array without first removing power from the electronics unit. Serious damage to the detector arrays and amplifier components could result.

The bias levels were set prior to shipment and should not require further adjustment. However, the following procedure can be used for bias verification if detector performance suggests that the bias requires readjustment.

Bias adjustment for the seven channels of Array 4 is accomplished in two steps. First, bias is applied to the bottom of the detector string. All seven detectors are attached to the heat sinks which are electrically common. This bias voltage is derived from a special bias supply which is part of the Array 4 Electronics Unit Power Supply (drawing 1308780, Reference 7). A schematic of the buffer amplifier and focal plane wiring is shown on drawing 1301037 (Reference 8). The nominal bias voltage required for the detector common is -17 volts. This voltage can be varied by adjusting the 10K trim potentiometer which is located on the small bias supply board. This bias supply is attached to the bottom of the electronics unit cabinet adjacent to the power supply board. The voltage is monitored between the protruding wire test point next to the potentiometer and the housing ground. Adjustments must be made with all seven amplifier cards installed. The second portion of the bias adjustment is accomplished by

TABLE I

ARRAY 4

SIGNAL AND NOISE VARIATION WITH TEMPERATURE

CHANNEL	26°K			27°K			28°K			29°K		
	SIGNAL	NOISE	SIG/NOISE	SIGNAL	NOISE	SIG/NOISE	SIGNAL	NOISE	SIG/NOISE	SIGNAL	NOISE	SIG/NOISE
16	143 (MV)	.070 (MV)	2042	150 (MV)	.070 (MV)	2142	180	.070	2571	190	.075	2533
17	66	.065	1015	71	.070	1014	79	.058	1362	81	.080	1012
18	56	.065	861	63	.066	954	69	.065	1061	68	.080	850
19	89	.075	1186	77	.082	939	85	.090	944	86	.100	860
20	60	.070	857	66	.073	904	66	.075	880	67	.080	837
21	96	.090	1066	87	.085	1023	79	.080	987	59	.080	737
22	74	.085	870	65	.083	783	59	.075	786	44	.066	666

NOTE: At 30°K channel 21 and 22 amplifiers limited in the positive direction.

adjusting the 1K trim potentiometer R7 (Schematic, LWS 4 Preamp Drawing No. 1308782, Reference 9) to provide the voltages listed below at the output of the first operational amplifier OA1 (pin 6) and cabinet ground. The R7 potentiometers are located on each Array 4 amplifier card at the input side of the card (the input side of the card has the "picture frame" ground shield). The optimum bias voltages as measured between cabinet ground and pin 6 of OA1 are:

Channel	Voltage
16	+3.0
17	+3.0
18	+3.0
19	+3.0
20	+9.0
21	+8.0
22	+8.0

The -17 volts applied to the detector common and the above voltages measured at OA1 pin six represent the optimum bias for the particular detectors of this focal plane. The bias was established during extensive testing in which various operating temperatures and bias settings were examined for maximum signal to noise ratios for the seven channels. It is not expected that the detector characteristics would change sufficiently to warrant adjustment of the bias to different levels.

Should it be necessary to perform a continuity check of the detectors and load resistors in the array, it is recommended that this operation be accomplished using a Hewlett Packard Model 412A ohmeter or equivalent in order to prevent possible opening of the .001-inch gold wires connecting the detectors and load resistors to the tape cable. In no case should a VOM (multi-meter i.e., Simpson, etc.) be used for this operation. Because the detectors have relatively low resistance at room temperature, it is possible to measure the series resistance of the load resistor/detector resistance at room temperature and obtain essentially the load resistance. The resistance can then be measured at operating temperature ($28^{o}K$) and the sum of the detector and load resistances will be obtained. The load resistances are tabulated below:

Channel	Load Resistance (Kohms)
16	100
17	430
18	430
19	340
20	215
21	100
22	100

Detector, load resistor and FET buffer connection are shown on Drawing 1301037 (Schematic Diagram LWS 4 Focal Plane, Reference 8).

5.3 Detector/Array Checkout and Bias Adjustment, Array 3

CAUTION

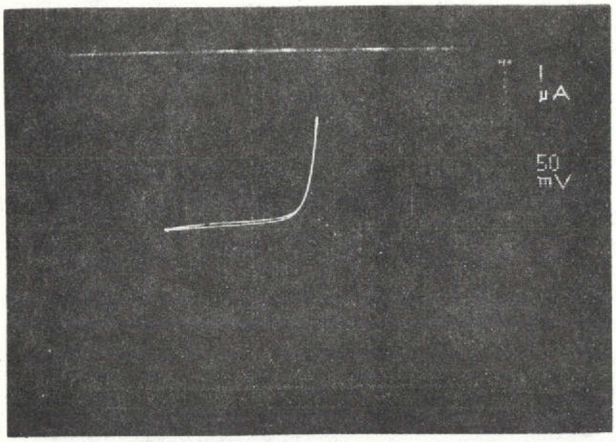
Never remove or replace amplifier cards or connect and disconnect the array from the electronic unit without first removing power from the electronics unit. Serious damage to the detector arrays and amplifier components could result.

The indium antimonide detectors of Array 3 are photovoltaic diodes which can be easily damaged by improper handling or application of voltages. These devices should never be connected to test equipment which could possibly supply current and damage the diode. If checkout of the detectors is indicated, they may be tested using a transistor curve tracer (Tektronix Model 575 or equivalent). However, it is extremely important that the reverse voltage does not exceed 200 millivolts and that the forward current does not exceed 200 miroamps. Photographs of the diode curves for the Array 3 devices (Figure 1) are included for reference. It is also very important that the amplifier bias is correctly established prior to connection of the array. The bias voltage was accurately set prior to delivery and further adjustment should not be required. However, if amplifier components are changed, the bias should be checked before connecting the amplifier to the Array. The bias setting can be checked by simulating the detector/load resistor combination at the amplifier input. Referring to Drawing 1308784 (Interconnect, LWS 3, Reference 4) and Drawing 1308783 (Schematic, LWS 3 Preamp, Reference 10) connect 100K resistors across Sig 1 to FB 1 (pins A and H) and FB 1 to Sig Com 1 (pins H and W) of the amplifier input connector (DBA 50-20-41SN, Deutsch). Apply amplifier power and adjust the bias trim potentiometer R6* to produce a voltage of less than 20 millivolts (referenced to case ground) at pin A. Similarly, channels 14 and 15 are also set using the 100K resistors and corresponding pins of the amplifier input connector. Having made the preliminary bias adjustments with the resistor simulators, the array may now be connected and the final bias adjustment can be made. For best performance, the bias should be set to 1 millivolt measured at Gate 1 of Q1(AD841) for all three channels.

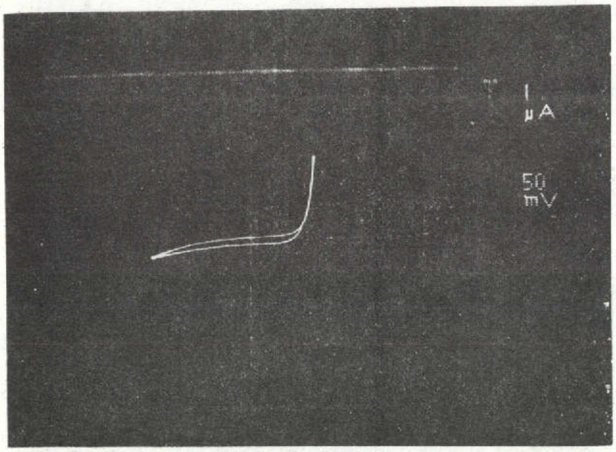
5.4 Gain Adjustments

The gain of the Array 3 channels was set to produce signals of 51, 70.5 and 400 millivolts for channels 13, 14 and 15 respectively when

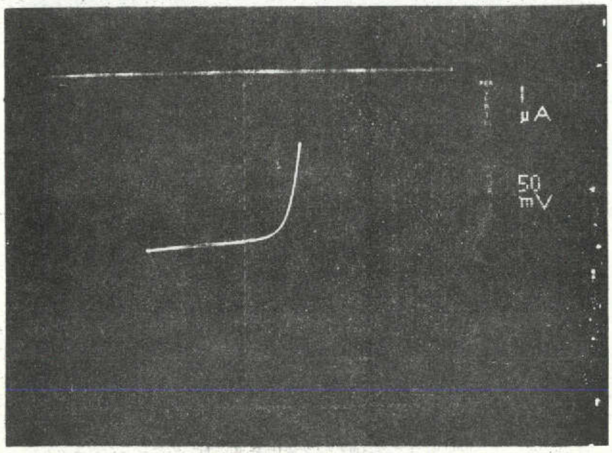
*Potentiometer R6 is located on each Array 3 Amplifier card at the input side of the card. (The input side of the card has the "picture frame" ground shield).



Channel 13



Channel 14



Channel 15

Figure 1
Array 3 Detector Diode Curves

operated under test conditions described in the Acceptance Test Procedure, AE-23233A dated 13 May 1974 (Appendix C). The signal levels may be adjusted over a fairly broad range (factor of 3 to 5) with the gain trim potentiometer R21 (Drawing 1308783, Reference 10). The gain trim adjustment is located at the output side of the board. The Array 4 amplifier gains have been set to provide the following signals when viewing the chopped blackbody source described in the acceptance test procedure.

Channel	Response (mv)
16	175
17	77
18	66
19	83
20	67
21	76
22	58

The signals were calculated to correspond to an MSS system output of 0.5 volts for a 20° ΔT target. As with Array 3, these levels may be changed over a relatively large latitude by the gain trim adjustment. This adjustment is located on output side of each amplifier card like Array 3. A discussion of the responsivity calculation is contained in the Acceptance Test Procedure, Appendix C.

6. DEWAR VACUUM

The two arrays were shipped at a pressure of approximately 1.5 x 10^{-6} Torr. This pressure is maintained through continuous operation of 2 liter per second Varian Vac-Ion* pumps. During shipment, the pumps were operated from battery packs, but 28 VDC power supplies should be substituted for the shipping batteries as soon as possible.

CAUTION

> High voltages are present at the pump input and pump power supplied (3500 volts). Refer to Paragraph 6.3 prior to working with the vacuum power supplies.

The dewars are equipped with vacuum seals consisting of a Kovar carrier with a .003" coating of Indium. These seals, which were specially developed during this program, are not reuseable. Leak rates of less than 3×10^{-8} atmosphere cc/second are easily achieved. If a problem occurs in which opening the dewar is indicated, consult AESC before proceeding.

Critical damage can be caused to the focal plane by venting the focal plane to room ambient pressure when the detector assembly is cooled below room temperature. Atmospheric constituents will precipitate onto all the cold surfaces (e.g., detectors, filters, etc.) and may cause mechanical damage as well as reduce the optical transmission/electro-optical performance of the detector array. If by accident the focal plane is vented to the room while cold, the bake-out procedure described below should be carefully followed.

6.1 Reestablishing System Vacuum

If it is necessary to connect the dewars to a large diffusion or VacIon pumping station, dewar connections have been provided. The most

*Vac-Ion Pump is a registered name and the pump is manufactured by Varian Vacuum Division, Palo Alto, California.

probable cause for connection to an external vacuum system would be if the integral VacIon pumps were stopped for a period of time and could not be restarted due to excess pressure, or if prolonged operation of the focal planes at the cryogenic temperatures condensed gases which on subsequent focal plane warming exceed the capacity of the pump/power supply combination.

6.2 Vacuum Valve Operation

When operating the vacuum valve, refer to the Varian Vacuum Division instructions for 3/4-inch all metal mini-valve 951-5014* (Reference 11). The dewars have been fitted with these valves and 90° elbows which permits pumping on the units while installed in the MSS. A flanged adapter and copper gaskets have been included with the spare parts for this purpose. The blank flanges which have been installed on the elbows are for protection from contamination only. The dewar seal is effected at the valve seat.

After checking for vacuum leaks the dewar assembly should be baked at $50^{\circ}C$ for 48 hours. During bake-out it is recommended that, initially, the focal plane be pumped down with a mechanical roughing pump, then by a high-capacity vac-ion pump (approximately 50 to 100 liter/sec) rather than an oil diffusion pump. If a heat bonnet is used during the bake-out cycle, the dewar window should be protected from bonnet outgassing products which would deposit contaminants onto the window.

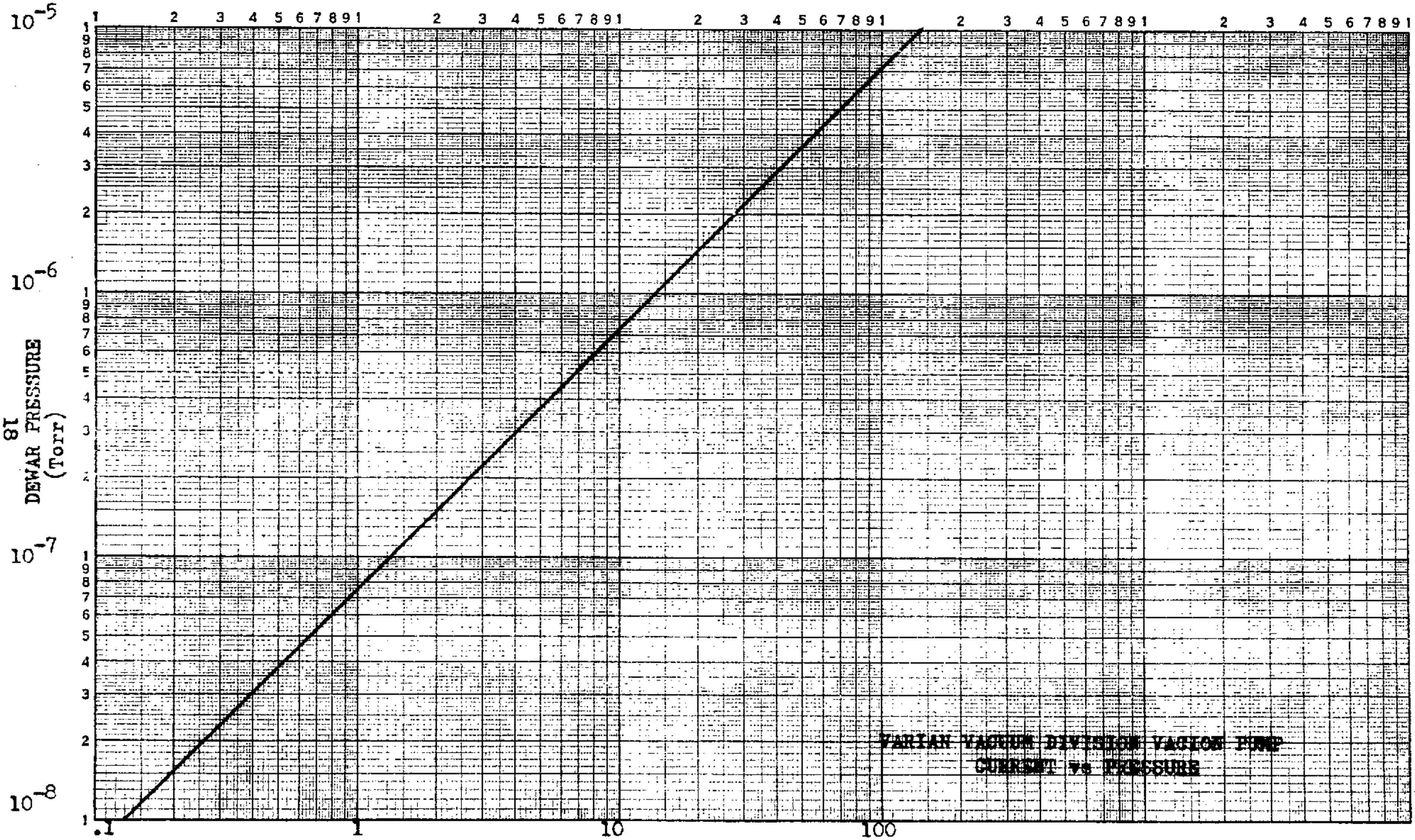
6.3 Ion Pump

The arrays are equipped with 2-liter per second vac-ion pumps. Extreme caution should be used when working on or around these units, due to the presence of high voltages. Under normal operating conditions, the

*Manufactured by Varian Vacuum Division, Palo Alto, California.

output voltage is typically 3500 volts (with currents as high as 10 ma).

When connecting the input power to the power supply, observe the polarity to prevent damage to the supply. The focal plane vacuum can be monitored by measuring the ion pump current and referring to the data sheet (Figure 2). If a vacuum leak check is required (utilizing a helium leak detector) the ion pump should be deactivated in advance of the vacuum leak check. Helium or argon may permanently and severely contaminate the pumping elements.



VACION PUMP CURRENT (microamps)

Figure 2

Appendix A

COOLER PERFORMANCE DATA

Report No. 5064

PRODUCTION TEST SUMMARY

MODEL 0120 CRYODYNE 77°K

Component	S/N
Drive Displacer Assy.	8100-460
Gearmotor Assy.	485
#1 Displacer	I 22
#2 Displacer	E — 64
Compressor Assy.	TEST UNIT
Compressor Pump	300
Adsorber	426
Cylinder No	346

Customer NASA

Case No. 8906-00

E. P. No. 3425-72 A

Test Date 7-20-73

Comments:

Tested in accordance with Spec. A3543-33 Rev. —

Ambient Temp. 75° °F

Test Data Summary:

Test No(s): 5

A. Cooldown

Time to 77°K: 32.95 min.

Total Mass: 100 grams

B. Stability

Second Stage Load: 2.6 watts

Stability Run Time: 4.03 hours

Maximum Variation: 0.3 K°

C. Performance

Second Stage Load - Watts	Second Stage Temp. - °K
0	39.1°K
1.0	54.0°K
2.0	71.0°K
2.6	76.9°K

D. Tipping Stability

Second Stage Load: 2.6 watts

Maximum Variation: 3.4 K°

E. Assurance

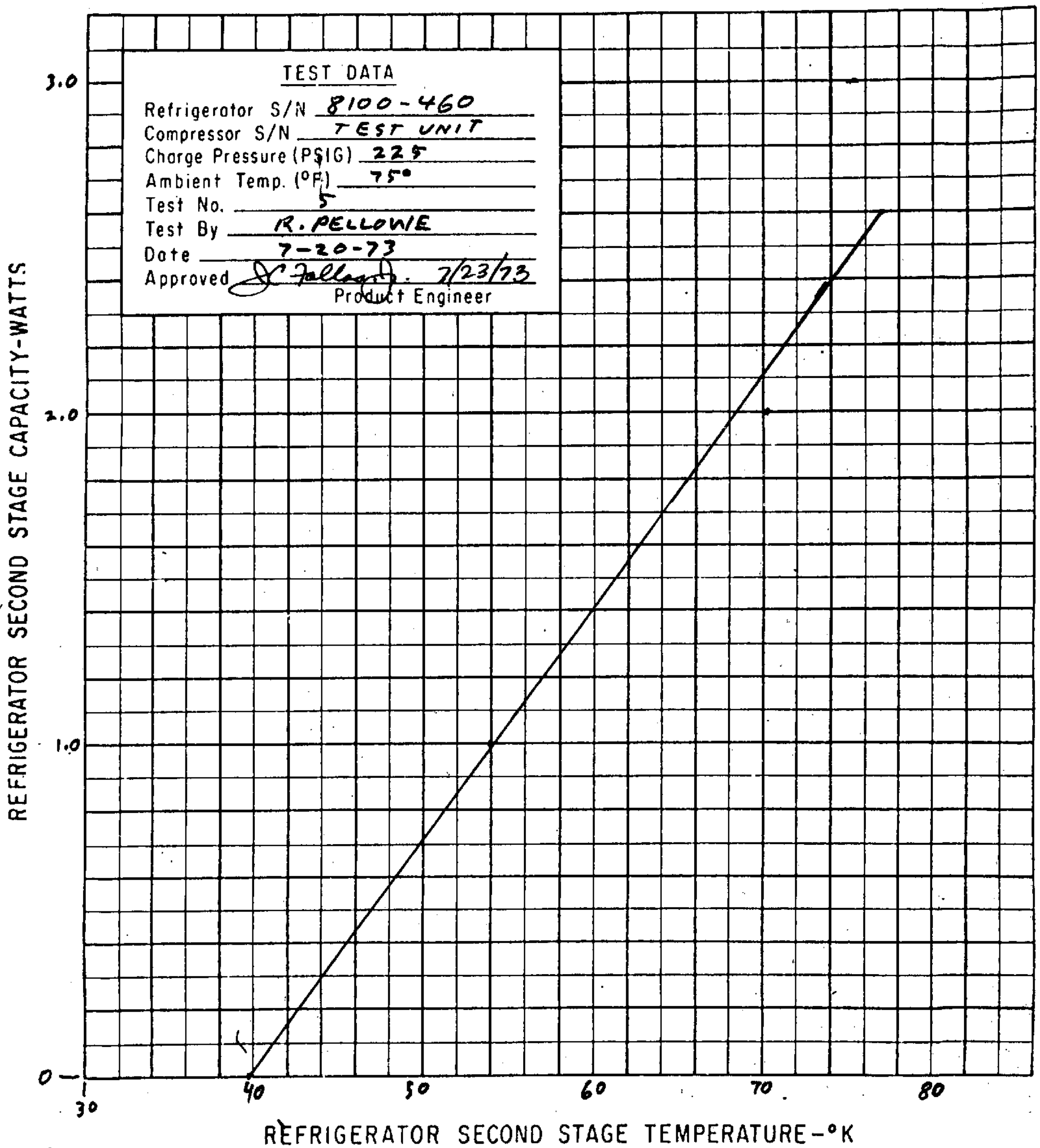
Total Operating Time During Final Acceptance Tests: 8.05 hours

Approval		Date	Approval		Date
Test Foreman	W. A. Mebelle	7-23-73	Quality Control	[signature]	7/23/73
Product Engineer	J C [signature]	7/23/73	Source Inspector		

Tested in accordance with CTI Specification ____

PERFORMANCE TEST RESULTS-MODEL CRYODYNE® COMPRESSOR

Report No. 5064



(MEASURED AT GRAM COPPER MASS WITH THERMAL ISOLATOR ATTACHED)

Refrigerator S/N 8100-460
Gearmotor Assy. S/N 485
#1 Displacer S/N I 22
#2 Displacer S/N E-64
Compressor Assy. S/N TEST UNIT
Compressor Pump S/N 300
Adsorber S/N 426
Cylinder 346

Displacer Assembly:
Push —
Pull —
Test Stand No. 1
Stage #2 Color RED
Customer NASA
E.P. # 3425-72A Case # 8900 00

Test No. 5 Sheet No. 1
Date 7-20-73
Tested By R. PELLOWE

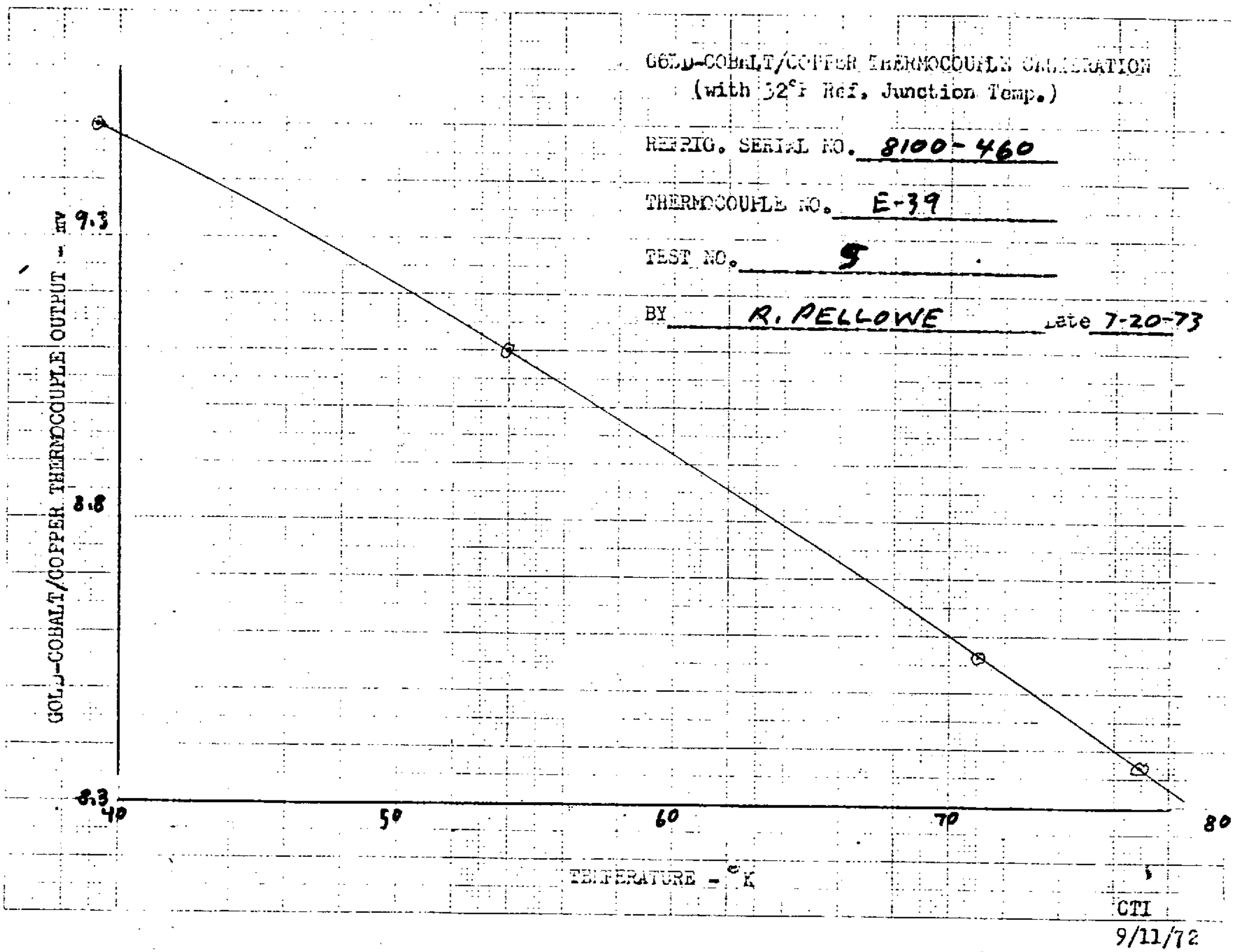
Rd. No.	Time Hours	Refrig. Temp. 1st [illegible]	Stg. 2 rdg	2nd Stg. Load Watts	Comp. Press. Supply psig	Comp. Press. Return psig	Comp. Disch. Temp. °F	System Current Amps	System Voltage Volts	Vacuum Microns	Ambient °F	Notes	
		—	95.2	—	225	225	75°	—	208	2237	75°		
	0713	—	95.2	—	289	52	75°	5.22	208	2237	75°	START	
1	0718	0.04	95.0	—	298	72	195°	3.18	208	19M	75°	5.02	
2	0723	1.98	94.3	—	295	90	210°	3.14	208	16M	75°	7.41	
3	0728	3.87	93.3	—	290	103	214°	3.06	208	16M	75°	8.41	
4	0733	5.49	91.9	—	288	112	214°	3.00	208	16M	75°	8.88	
5	0738	6.83	89.9	—	282	120		2.94	208	15M	75°	9.16	
	0745	PLUS	57	SECONDS	TO	77°K						32.95 MIN.	
6	0855	9.499	0.0	0.0	268/275	125/135	204°	2.80	207	1.1X10-5	75°	9.450	39.1°
	0857	LOAD	1.0	WATTS									
7	0930	9.100	0.0	1.0	271/276	120/135	205°	2.77	207	1.2X10-5	75°	9.379	54.0°
	0933	LOAD	2.0	WATTS									
8	1032	8.562	2.7	2.0	273/278	120/135	207°	2.77	207	1.4X10-5	75°	9.299	71.0°
	1035	LOAD	TO 77°										
9	1138	8.370	13.9	2.6	274/279	120/135	209°	2.77	206	1.5X10-5	75°	9.247	76.9°
	1143	TIP	90°	CW									
10	1202	8.370	14.6	2.6	274/279	120/135	209°	2.77	206	1.6X10-5	75°	9.229	

MODEL 0120 CRYODYNE TEST DATA LOG

Refrigerator S/N 8100-460 Test No. 5 Sheet 2 of 2

Compressor S/N TEST UNIT Date 7-20-73

Rd. No.	Time Hours	Refrig. Temp. Stg. 2 mv	Refrig. Temp. Stg. 2 psia	2nd Stg. Load Watts	Comp. Press. Supply psig	Comp. Press. Return psig	Comp. Disch. Temp.-°F	System Current Amps	System Voltage Volts	Vacuum Microns	Ambient °F	Notes
[illegible]	1205	TIP	180°	CW								
11	1222	8.265	20.6	2.6	274/279	120/135	209°	2.77	206	1.5×10^{-5}	75°	9.245
	1224	'TIP	270°	CW								
12	1247	8.300	18.0	2.6	274/279	120/135	209°	2.77	206	1.6×10^{-5}	75°	9.222
	1249	RETURN		TO	VERTICAL							
13	1316	8.350	15.1	2.6	274/279	120/135	210°	2.77	206	1.6×10^{5}	75°	9.252
14	1518	8.350	15.0	2.6	274/279	120/135	212°	2.79	205	1.8×10^{5}	75°	9.260 SHUTDOWN


GOLD-COBALT/COPPER THERMOCOUPLE CALIBRATION
(with 32°F Ref. Junction Temp.)
REFRIG. SERIAL NO. 8100-460
THERMOCOUPLE NO. E-39
TEST NO. 5
BY R. PELLOWE Date 7-20-73
GOLD-COBALT/COPPER THERMOCOUPLE OUTPUT - mV
9.3
8.8
8.3
40
50
60
70
80
TEMPERATURE - °K
CTI
9/11/72

PRODUCTION TEST SUMMARY

MODEL 0120 CRYODYNE

Report No. 5064

omponent	S/N
frigerator	8100-459
earmotor Assy.	372
#1 Displacer	V-24
2 Displacer	E-58
Compressor Assy.	Test Unit
ompressor Pump	278
Adsorber	426
Cylinder	345

Customer NASA

Case No. 890000

E. P. No. 3425-72A

Test Date 7-6-73 — 7-7-73

Comments:

Test Data Summary:

Test No(s): 2

A. Cooldown

Limit: 30 min. with 50 gram mass

Time to 25°K: 33.05 min.

Total Mass: 105 grams

B. Stability

Limit: 3 K° maximum over a 4-hour period with 0.5 watt heat load.

Second Stage Load: 0.5 watts

Stability Run Time: 14.2 hours

Maximum Variation: 1.6 K°

C. Performance

Limit: See Specification Curves.

Second Stage Load - Watts	Second Stage Temp. - °K
0	14.9°
0.5	16.3°
1.0	18.2°

D. Tipping Stability

Limit: 3 K° maximum with a 0.5 watt heat load.

Second Stage Load: 0.5 watts

Maximum Variation: 2.5 K°

E. Assurance

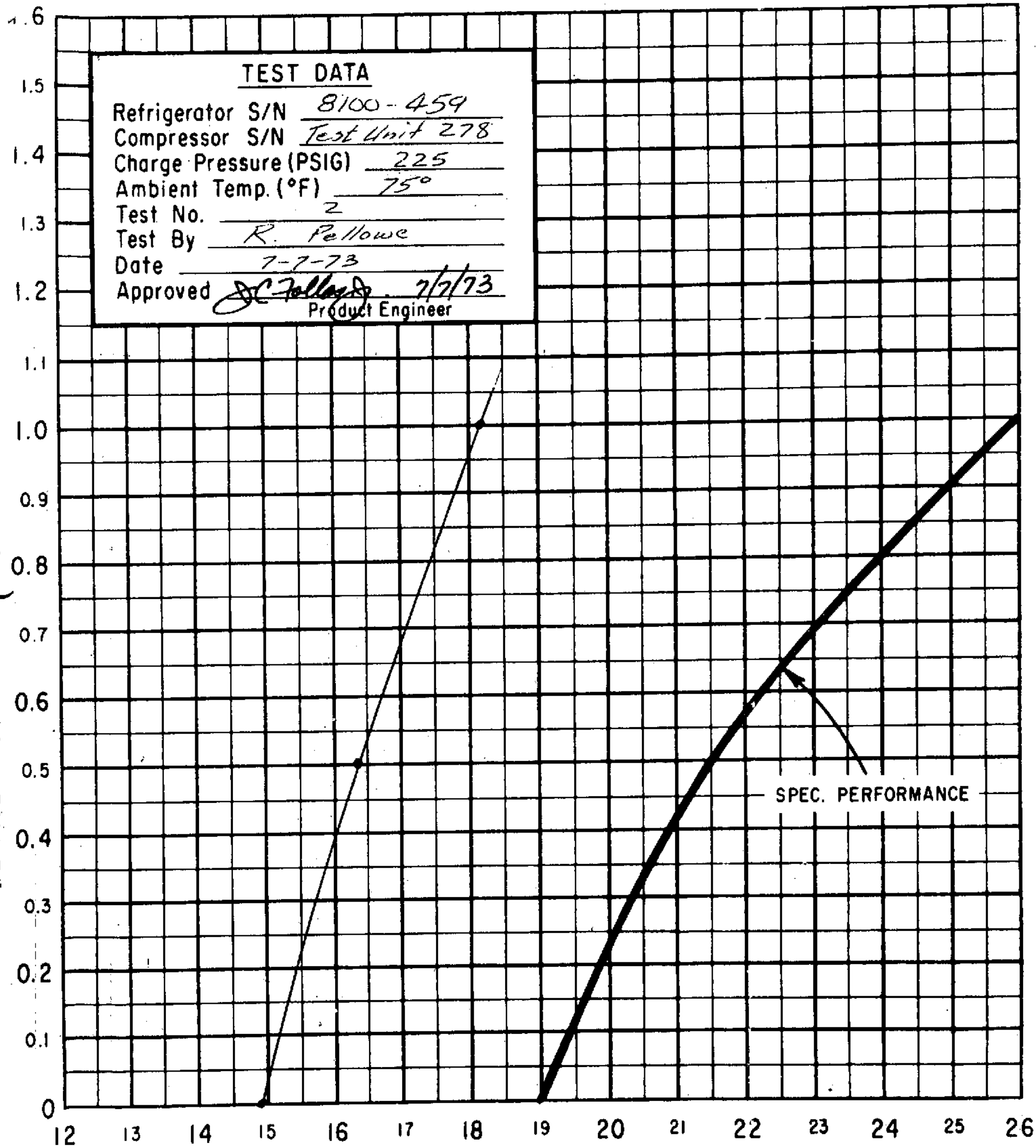
Limit: 10 hours minimum

Total Operating Time During Final Acceptance Tests: 23.1 hours

	Approved	Date
Test Foreman	W. A. Melville	7-7-73
Quality Control	[signature]	7-9-73
Product Engineer	J C [signature]	7/7/73

PERFORMANCE TEST RESULTS-MODEL 0120 CRYODYNE®

RC 30 COMPRESSOR



REFRIGERATOR SECOND STAGE TEMPERATURE-°K

(MEASURED AT ~~32~~ 67 GRAM COPPER MASS WITH THERMAL ISOLATOR ATTACHED)

[illegible]

Refrigerator S/N 8100 - 459
Gearmotor Assy. S/N 372
#1 Displacer S/N V-24
#2 Displacer S/N ——
Compressor Assy. S/N TEST UNIT
Compressor Pump S/N 278
Adsorber S/N 426

Displacer Assembly:
Push 1.75 lbs.
Pull 2.25 lb
Test Stand No. 2 (FLANGE # 2)
Stage #2 Color BLUE
Customer NASA
E.P. # 3425-72A Case # 890000

Test No. 2 Sheet No. 1
Date 7-6-77
Tested By R Pellowe

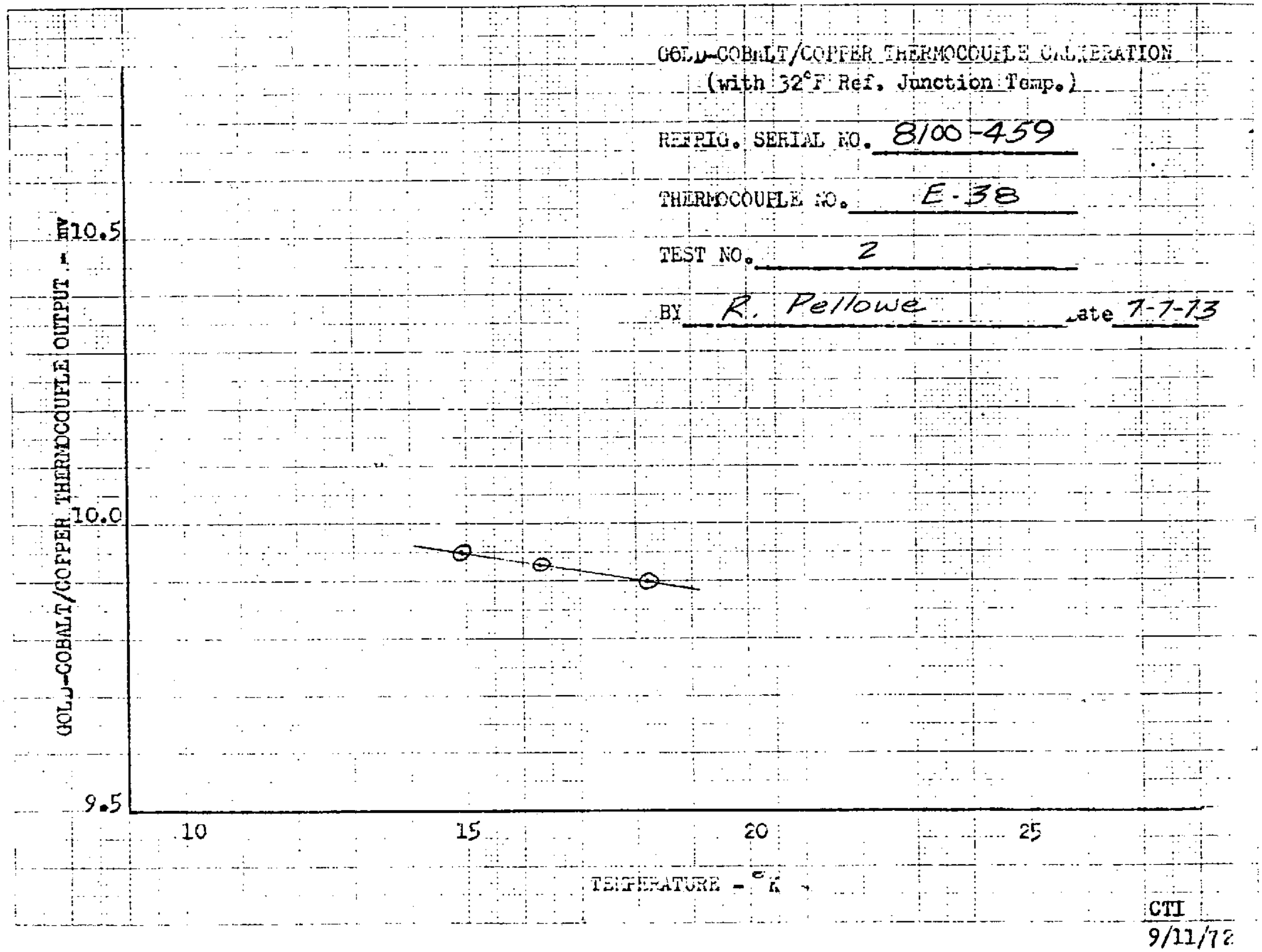
Rd. No.	Time Hours	R. Frig. [illegible] °K	Temp. Stg. 2 psia	2nd Stg. Load Watts	Comp. Press. Supply psig	Comp. Press. Return psig	Comp. Disch. Temp °F	System Current Amps	System Voltage Volts	Vacuum Microns	Ambient °F	Notes
		—	99.8	—	225	225	75°	—	208	25M	75°	
	0756	—	99.8	—	285	52	75°	4.45	208	25M	75°	START
1	0801	0.40	99.5	—	294	67	195°	3.20	208	20M	75°	
2	0806	2.27	99.0	—	292	85	216°	3.30	208	19M	75°	
3	0811	4.07	98.1	—	290	95	225°	3.13	208	19M	75°	
4	0816	5.63	97.0	—	286	103	226°	3.05	208	21M	75°	
5	0821	7.11	94.8	—	284	108	224°	2.96	208	21M	75°	
6	0826	8.62	90.2	—	280	113	223°	2.93	208	18M	75°	
	0829	PLUS 3 SECONDS TO 26°K										33.05
7	0940	9.932	2.3	0.0	265	127/134	208°	2.74	208	3.0×10^{-5}	75°	
	0942	LOAD 1.5 WATTS										
8	1007	9.860	14.6	1.5	268	127/131	210°	2.75	208	2.9×10^{-5}	75°	
	1010	LOAD 1.0 WATT										
9	1041	9.900	6.8	1.0	267	125/132	208°	2.75	208	2.7×10^{-5}	75°	
	1043	LOAD 0.5 WATT										
10	1117	9.929	2.9	0.5	265	126/133	207°	2.74	208	2.5×10^{-5}	75°	
	1121	TIP 45° CW										

MODEL 0120 CRYODYNE TEST DATA LOG

Refrigerator S/N 8100-459 Test No. 2 Sheet 2 of ___

Compressor S/N TEST UNIT Date 7-6-73

Rd. No.	Time Hours	Refrig. Temp. Stg. 2 mv	Refrig. Temp. Stg. 2 psia	2nd Stg. Load Watts	Comp. Press. Supply psig	Comp. Press. Return psig	Comp. Disch. Temp.-°F	System Current Amps	System Voltage Volts	Vacuum Microns	Ambient °F	Notes
11	1136	9.934	2.3	0.5	265	127/133	207°	2.75	208	2.5×10^{-5}	75°	
	1139	TIP	45°	CCW								
12	1156	9.911	5.1	0.5	265	127/137	206°	2.75	208	2.4×10^{-5}	75°	
	1158	RETURN		TO	VERTICAL							
13	1221	9.922	3.3	0.5	265	126/132	206°	2.75	208	2.4×10^{-5}	75°	
14	1650	9.921	3.5	0.5	265	125/133	207°	2.70	208	2.2×10^{-5}	75°	
					7-7-73							
15	0700	9.920	3.6	0.5	266	130	209°	2.75	208	2.0×10^{-5}	73°	
	0704	Removed		Load								
16	0730	9.950	1.1	0.0	265	130	209	2.75	208	2.0×10^{-5}	73°	
	0732	Shut	down									


GOLD-COBALT/COPPER THERMOCOUPLE CALIBRATION
(with 32°F Ref. Junction Temp.)
REFRIG. SERIAL NO. 8100-459
THERMOCOUPLE NO. E-38
TEST NO. 2
BY R. Pellowe Date 7-7-73
GOLD-COBALT/COPPER THERMOCOUPLE OUTPUT - MV
10.5
10.0
9.5
10
15
20
25
TEMPERATURE - °K
CTI
9/11/72

Appendix B

DRAWING LIST

NASA LWS ARRAYS 3 & 4

DRAWING LIST

NASA LWS ARRAYS 3 AND 4

CONTRACT NAS9-13189

PART NUMBER	REV	DRAWING TITLE
1300066	B	Frame, Window Retaining LWS 4
1300076	A	Sleeve, Insulating LWS 3 & 4
1300356	A	Heat Sink, Detector Element 17, 18, 19, 20 LWS 4
1300357	A	Heat Sink, Detector Element 21 LWS 4
1300979	NC	Bearing, Thrust - Rotary Translation Stage LWS - 3 & 4
1300981	NC	Plate, Clamp, Lower - Rotary Translation Stage (Lower Part, Array Support) LWS - 3 & 4
1300982	A	Translation Stage Modification LWS - 3 & 4
1300983	NC	Base Plate - Translation Stage (Lower Part of Elevator) LWS - 3 & 4
1300984	NC	Table - Translation Stage (Upper Part of Elevator) LWS - 3 & 4
1300985	NC	Gear Set - Translation Stage (Used in Elevator) LWS - 3 & 4
1300986	NC	Shaft Set - Translation Stage (Used in Elevator) LWS - 3 & 4
1300987	NC	Guide, Shaft - Translation Stage (Used in Elevator) LWS - 3 & 4
1300988	NC	Lock, Guide - Translation Table (Used in Elevator) LWS - 3 & 4
1300989	NC	Lock, Position - Translation Stage (Used on All Stages) LWS - 3 & 4
1300990	NC	Translation Stage - Elevation (Evevator Assy) LWS - 3 & 4
1300991	NC	Plate, Clamp, Upper - Rotary Translation Stage (Upper Part Array Support) LWS 3 & 4
1300992	NC	Base Plate, Rotary Translation Stage (Partial Assy) LWS - 3 & 4

DRAWING LIST (Continued)

CONTRACT NAS9-13189

PART NUMBER	REV	DRAWING TITLE
1300993	A	Wheel, Worm - Rotary Translation Table LWS - 3 & 4
1300994	NC	Tape Cable (Signal) LWS-4
1300995	B	Detector Assembly - Element #15 LWS-3
1300996	B	Detector Assembly - Element #14 LWS-3
1300997	B	Detector Assembly - Element #13 LWS-3
1300998	B	Detector, Set LWS-3
1301000	A	Focal Plane/Cryocooler - LWS InSb Array #3 (Main Assy)
1301001	NC	Housing, Cold Finger LWS - 3 & 4
1301014	C	Heat Station 27K (On CTI Cooler) LWS-4
1301015	C	Heat Station 77°K (On CTI Cooler) LWS-3
1301016	NC	Housing, Focal Plane LWS-4
1301017	A	Window, Germanium LWS-4
1301018	A	Window, Sapphire LWS-3
1301019	NC	Housing, Focal Plane LWS-3
1301020	NC	Installation Drawing, LWS Arrays 3 and 4
1301021	A	Heat Sink, Master LWS-4
1301022	A	Cold Stop LWS-3

DRAWING LIST (Continued)
CONTRACT NAS9-13189

PART NUMBER	REV	DRAWING TITLE
1301023	A	Cold Stop LWS-4
1301024	A	Isolator, Cold Finger LWS-3
1301025	A	Isolator, Cold Finger LWS-4
1301026	A	Heat Sink, Master LWS-3 (2 Sheets)
1301027	NC	Heat Sink, Detector Element #13 LWS-3
1301028	A	Heat Sink, Detector Element #14 LWS-3
1301029	NC	Heat Sink, Detector Element #15 LWS-3
1301030	A	Focal Plane Assy. LWS-3
1301031	A	Tape Cable (Signal) LWS-3
SK-1301032	NC	Mount-Support, Cryodyne (Collar for MSS) LWS 3 & 4
1301033	A	Support, Bracket, Buffer Amplifier (Alumina Circuit Board Support) LWS-3
1301034	NC	Clamp Block, Side LWS-4
1301035	NC	Support, Tape Cable (Part of Signal Tape Cable Assy) LWS-4
1301036	A	Printed Wiring Board - Buffer Amplifier LWS-4
1301037	A	Schematic Diagram, Buffer Amplifier LWS-4
1301038	A	Component Board Assembly, Buffer Amplifier LWS-4
1301039	B	Support, Tape Cable, Heater and Temp Sensor (Part of Tape Assy) LWS-4

DRAWING LIST (Continued)

CONTRACT NAS9-13189

PART NUMBER	REV	DRAWING TITLE
1301040	A	Multispectral Focal Plane (Focal Plane Assy) LWS-4
1301041	NC	Filter, Spectral (Array 3 Filters) LWS-3
1301042	NC	Filter, Spectral (Array & Filters) LWS-4
1301043	A	Plate, Support - #13 Filter LWS-3
1301044	A	Plate Support - #14 Filter LWS-3
1301045	A	Plate Support - #15 Filter LWS-3
1301046	B	Frame, Window Retaining LWS-3
1301047	A	Printed Wiring Board, Buffer Amplifier (Blank) LWS-3
1301048	NC	Tape Cable - Signal LWS-4
1301049	NC	Shaft- Rotary Translation Stage LWS-3 & 4
1301050	A	Focal Plane/Cryocooler - LWS Ge:HG Array #4 (Top Assy)
1301175	NC	Rotary Translation Stage (Assembly) LWS-3 & 4
1301176	NC	Shim-Thrust Bearing (Used on Rotary Stage) LWS-3 & 4
1301177	NC	Adapter-Translation (Mounting Base) Stage LWS-3
1301178	NC	Detector Element, Channels 17, 18, 19, & 20 LWS-4
1301179	NC	Detector Element, Channels 16, 21, & 22 LWS-4

DRAWING LIST (Continued)

CONTRACT NAS9-13189

PART NUMBER	REV	DRAWING TITLE
1301180	NC	Detector Assy, Array 4 (Mounting of Detectors 17, 18, 19, 20)
1301181	NC	Detector Assy, Array 4 (Assy of Heat Sinks & Detectors)
1301185	A	Support, Tape Cable - Heater & Temp Sensor (Part of Tape Cable)
1301186	NC	Printed Wiring Board (Shows Tracks on Board) LWS 3
1301187	A	Component Board Assembly - Focal Plane (Load Resistors on Wiring Board) LWS 3
1301188	NC	Spacer, Component Board - Buffer Amplifier LWS-4
1301189	A	Tape Cable (Temp Control) LWS 3 & 4
1301190	A	Tape Cable - Heater and Temp Sensor (Assy) LWS 3 & 4
1308136	NC	Extender Pin, Connector (Temp Control) LWS 3 & 4
1308137	A	Schematic Diagram - LWS 3 Focal Plane
1308138	NC	Frame, Filter LWS 4
1308139	NC	Filter Asignment Aid, LWS 4 Focal Plane
1308140	NC	Housing, Cold Finger Mod I Spares (Contract Amendment 3S)
1308141	NC	Housing Spares (Contract Amendment 3S)
1308142	NC	Housing, Machined, Focal Plane Spares (Contract Amendment 3S)
1308143	NC	Housing, Machined, Focal Plane Spares (Contract Amendment 3S)

DRAWING LIST (Continued)

CONTRACT NAS9-13189

PART NUMBER	REV	DRAWING TITLE
1308148	NC	Shim, Focal Plane, LWS 4
1308780	NC	Schematic, Power Supply
1308781	NC	Schematic, Temp Control
1308782	NC	Schematic, Preamplifier, LWS 4
1308783	NC	Schematic, Preamplifier, LWS 3
1308784	NC	Interconnection Diagram, LWS 4
1308785	NC	Interconnection Diagram, LWS 3
1308786	NC	Housing, Electronics Unit

Appendix C

ACCEPTANCE TEST PROCEDURE

ACCEPTANCE TEST PROCEDURE FOR LONG WAVELENGTH SPECTROMETER FOCAL PLANE ASSEMBLIES

I. INTRODUCTION

This acceptance test procedure includes the inspection and performance evaluation of the Long Wavelength Spectrometer (LWS) developed under NASA contract NAS 9-13189 Amendment No. 1 S. The LWS is comprised of two major subassemblies: Array 3 with three Indium Antimonide detector channels and Array 4 with seven Mercury doped Germanium detector channels. Each array is mounted on a government furnished cryogenic cooler (Cryogenic Technology Inc. Model 120 with Aerojet designed cold station) and includes the vacuum housings, mounting hardware, and detector signal conditioning, temperature control and monitoring electronics. TheArrays and associated equipment have been designed for installation in the existing multispectral scanner currently being operated by the NASA Manned Spacecraft Center, Facility and Laboratory Support Branch. The purpose of this procedure is to demonstrate conformance to the Specification set forth in Section 4 of modification 1 S to NASA contract NAS 9-13189.

The two Arrays have been designed to operate independently and testing will be performed on each Array separately. The procedures will be the same for each Array. An Acceptance Test Data Sheet is included as Appendix B in this procedure to record the results of the tests discussed in the following paragraphs and as required in the Statement of Work (paragraph 4.4.3).

A. Detectivity (D^*) Measurments

Detectivity measurements will be made with a 500°K blackbody and 1000 Hz chopper using the system electronics assembly (power supply, amplifier and temperature conditioning circuits). A functional block diagram of the test equipment is shown in Figure 1. Signal and noise measurements are obtained using a Hewlett Packard Model 304A Wave Analyzer.

The minimum signal to noise ratio has been computed for each channel according to the relationship:

$$S/N = D^*_\lambda H\left(\frac{A}{\Delta f}\right)^{1/2}$$

where:

D^*_λ = minimum specified detectivity in the spectral band for the detector filter combination at a frequency of 1000 Hz.

A = detector area, cm^2

Δf = bandwidth of the wave analyzer used 6 Hz for this test

H = irradiance reaching the detector, $watts/cm^2$

The value of the irradiance has been calculated for each channel based on a blackbody temperature of 500°K with a 0.2 in. aperture. The array focal planes are mounted 14.38 in. from the source aperture. The rms irradiance H is listed in Table I and was computed according to the relationship:

$$H_{rms} = W_{\Delta\lambda} \frac{d^2}{4\ D^2} M_f T_w$$

where:

$W_{\Delta\lambda}$ = radiant emittance, watts cm^{-2}. $W_{\Delta\lambda}$ was calculated using the nominal transmission characteristics of the array filters and the blackbody energy less background energy contained in the filter bandpass.

d = aperture diam, in. (0.2" aperture for these tests)

M_f = rms conversion factor for chopper/aperture geometry (0.384 for 0.2" aperture and test chopper disc)

T_w = average window transmission in the channel spectral band

D = distance of detector from blackbody aperture (14.38 in.)

B. Responsivity vs Frequency Measurements

It is not possible with available blackbody sources and modulators to demonstrate array frequency response beyond 25 kHz, due to mechanical chopping limitations. Furthermore, use of a LED for frequency response demonstration is not possible with the final assembly because the LED emission (approximately 5.5 μm) is not in the passband of the channel filters which have been installed in front of the detectors.

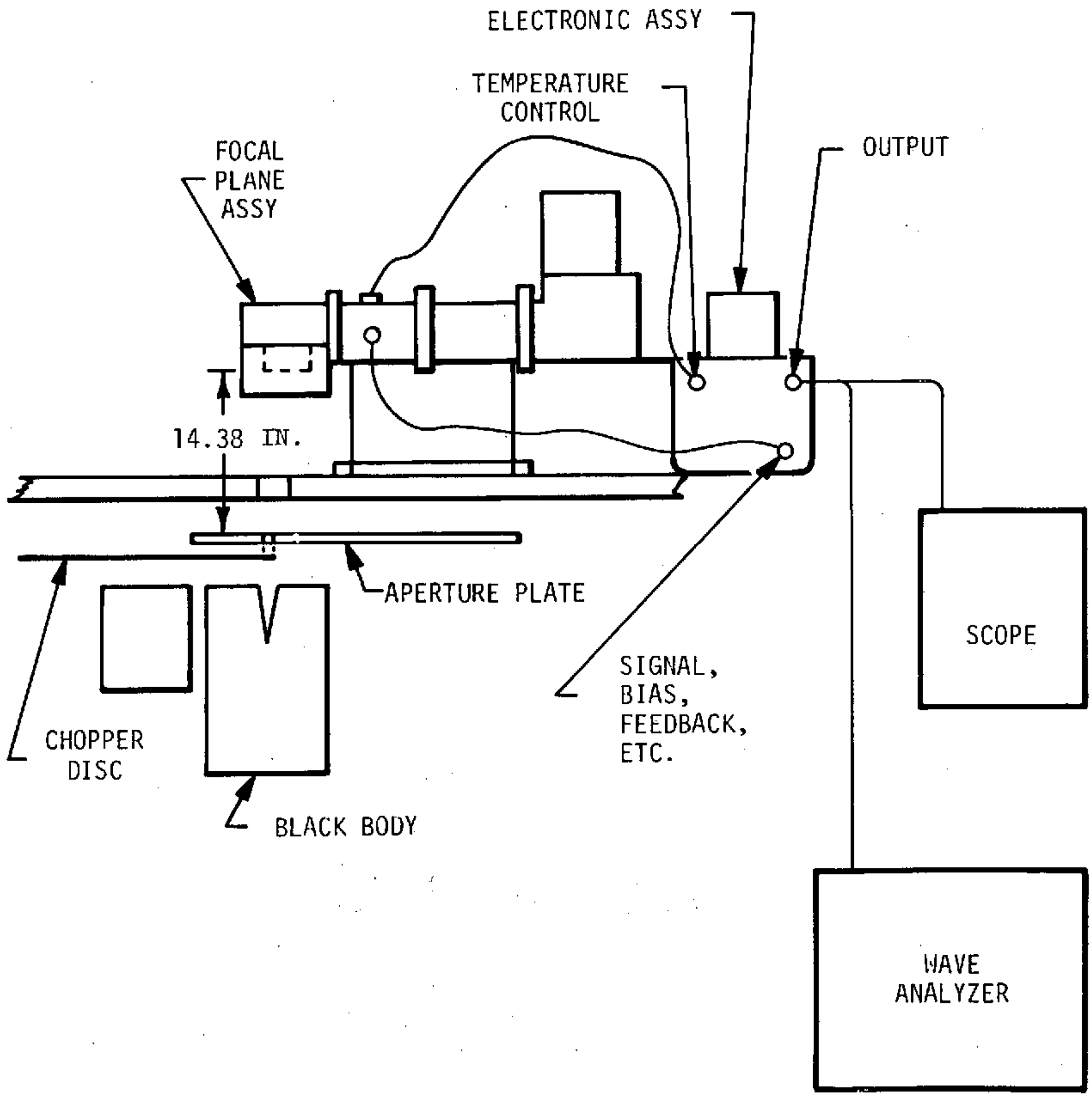


FIGURE 1 DETECTIVITY MEASUREMENT TEST SET-UP

TABLE I

CALCULATED ARRAY PERFORMANCE REQUIREMENTS

Channel	λ_o μ	$\Delta\lambda$ μ	A cm^2	T_W	$H_{\Delta\lambda}(BB)$ w/cm^2	$\varphi_{\Delta\lambda}(BB)$ $ph/cm^2\text{-sec}$	$\varphi_{\Delta\lambda}(20^o)$ $ph/cm^2\text{-sec}$	S mV	D^*_λ $cm\ Hz^{1/2}/W$	S/N
13	2.23	0.26	.0309	0.97	8.11×10^{-9}	9.47×10^{10}	8.61×10^{9}	5400	3×10^{11}	175
14	3.77	0.46	.0362	0.95	1.91×10^{-7}	3.83×10^{12}	3.37×10^{12}	570	3×10^{11}	4475
15	4.63	0.25	.0195	0.78	1.26×10^{-7}	3.76×10^{12}	1.05×10^{13}	179	3×10^{11}	2145
16	6.50	1.00	.0394	0.88	6.04×10^{-7}	2.23×10^{13}	6.42×10^{13}	175	4×10^{10}	1958
17	8.55	0.50	.0195	0.88	2.15×10^{-7}	1.05×10^{13}	6.82×10^{13}	77	4×10^{10}	489
18	9.05	0.50	.0195	0.91	2.00×10^{-7}	1.00×10^{13}	7.59×10^{13}	66	4×10^{10}	457
19	9.55	0.50	.0195	0.93	1.83×10^{-7}	9.47×10^{12}	5.69×10^{13}	83	4×10^{10}	419
20	10.55	0.90	.0355	0.90	2.55×10^{-7}	1.50×10^{13}	1.12×10^{14}	67	4×10^{10}	783
21	11.50	1.00	.0394	0.78	1.97×10^{-7}	1.46×10^{13}	9.64×10^{13}	76	4×10^{10}	640
22	12.50	1.00	.0394	0.66	1.33×10^{-7}	1.26×10^{13}	1.10×10^{14}	58	4.5×10^{10}	484

For both arrays, signal response vs frequency will be measured up to the limit of the blackbody/chopper system. Response at frequencies up to 250 kHz will be measured on Array 3 by injecting an external signal current at the detector-feedback resistor node. This signal injection technique satisfactorily simulates the signal current generated by the detector in response to signal radiation.

For Array 4, signal and noise frequency characteristics are expected to be substantially identical. Consequently, the noise voltage spectrum will be measured at frequencies up to 250 kHz with this measurement taken to be equivalent to signal response.

C. Spectral Response

A typical detector spectral response for both Array 3 and Array 4 is provided in Appendix C along with the filter transmission data provided by the filter supplier, Optical Coating Laboratories Incorporated. From this data the spectral response of the array channels can be readily determined.

D. Wideband Noise Measurements

Wideband noise measurements will be made using a Ballantine Laboratories Model 323 true RMS voltmeter with only background energy present and no signal applied.

E. Detector, Preamplifier Responsivity - Output Signal Level

System gain adjustments have been made for channels 16-22 such that a target temperature change of 20°C will produce a 0.5 volt rms signal from the amplifier. These adjustments were made using the relationship:

$$S = 0.5 \text{ V} \times \frac{\varphi_{\Delta\lambda}(\text{BB})}{\varphi_{\Delta\lambda}(20^{\circ})}$$

where

S = amplifier output, rms volts

$\varphi_{\Delta\lambda}(\text{BB})$ = photon flux at detector within spectral band due to 500°K background)), ph/cm^2-sec

$\varphi_{\Delta\lambda}(20^{\circ})$ = photon flux at detector within spectral band due to 320° target in 300°K background as seen by the MSS, ph/cm^2-sec

The photon fluxes $\varphi_{\Delta\lambda}$ for the 300°K to 500°K, and the 300°K to 320°K ranges in the bandpass for each channel are also listed in Table I. Thus, the gain can be set for each channel of the arrays using a chopped 500° blackbody (with a 300° chopper blade) by adjusting the output voltage to the calculated values.

Adjustment of the output signal level to provide .5 volt for an MSS target ΔT of 20°C is not feasible or desireable for channels 13 thru 15. Therefore these channel gains have been adjusted to provide a noise level of approximately 50 mv rms.

Minor gain adjustments following installation in the MSS may be accomplished with the trim potentiometer provided for this purpose.

F. Zero Restore Performance

Zero-restore performance of the amplifier units will be demonstrated without use of the detector arrays. (Simulation of the blackbody reference used in the MSS would require a rather complex test set-up which can be simulated satisfactorily at less expense). For these tests, signal simulation is provided by an oscillator, power supply, and FET switch to generate a sine wave signal periodically interrupted by a reference pedestal. (See Figure 2) The reference pedestal, simulating the blackbody reference signal, is produced by the first pulse generator, while the delayed zero restore pulse is produced by the second generator. Performance of the zero restore function can be observed on the direct coupled oscilloscope.

G. Temperature Control

The temperature control system provided for each array maintains the respective array detector heat sink at the optimum detector operating temperature. These temperatures are nominally 77°K and 28°K for Array 3 and Array 4 respectively. The heat sinks are fitted with thermistor temperature sensors for (1) sensing and controlling about the established optimum temperature and (2) monitoring the actual temperature. The temperature control and monitor meter driver circuitry are mounted on a separate card in each of the electronics assemblies. The circuit provides adjustment of the control temperature with a trim potentiometer in the input bridge.

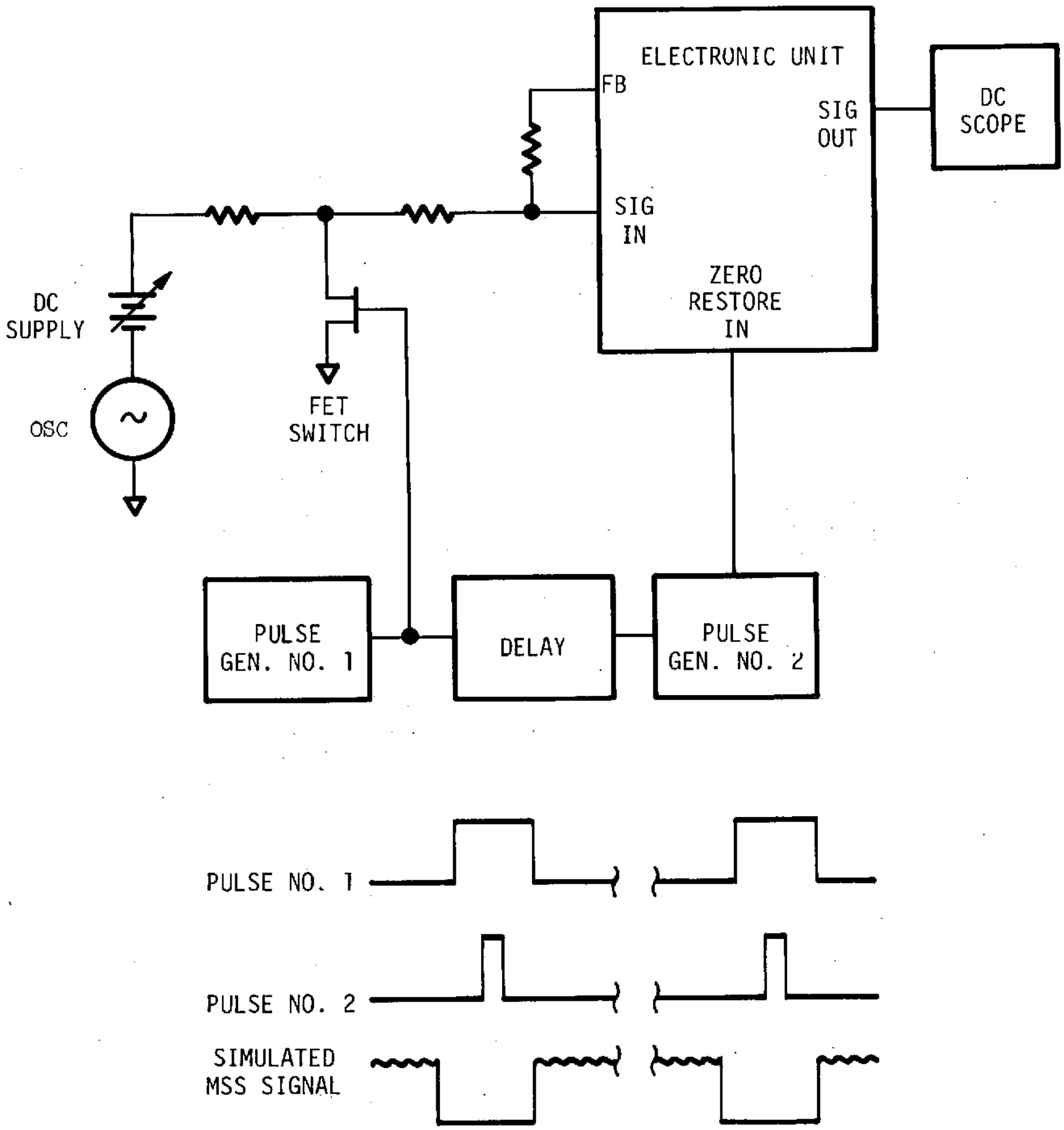
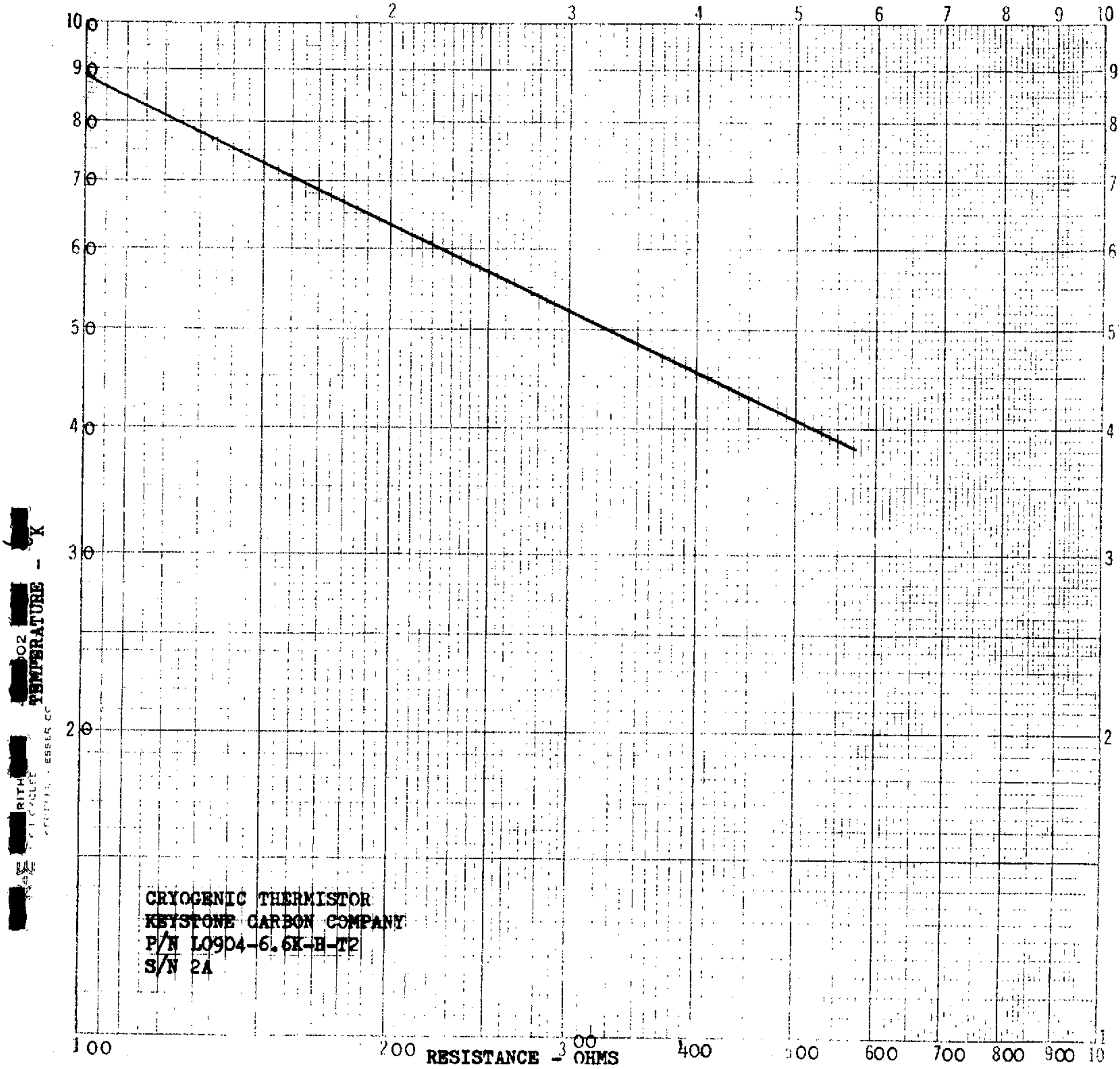


FIGURE 2 ZERO RESTORE DEMONSTRATION TEST SET-UP

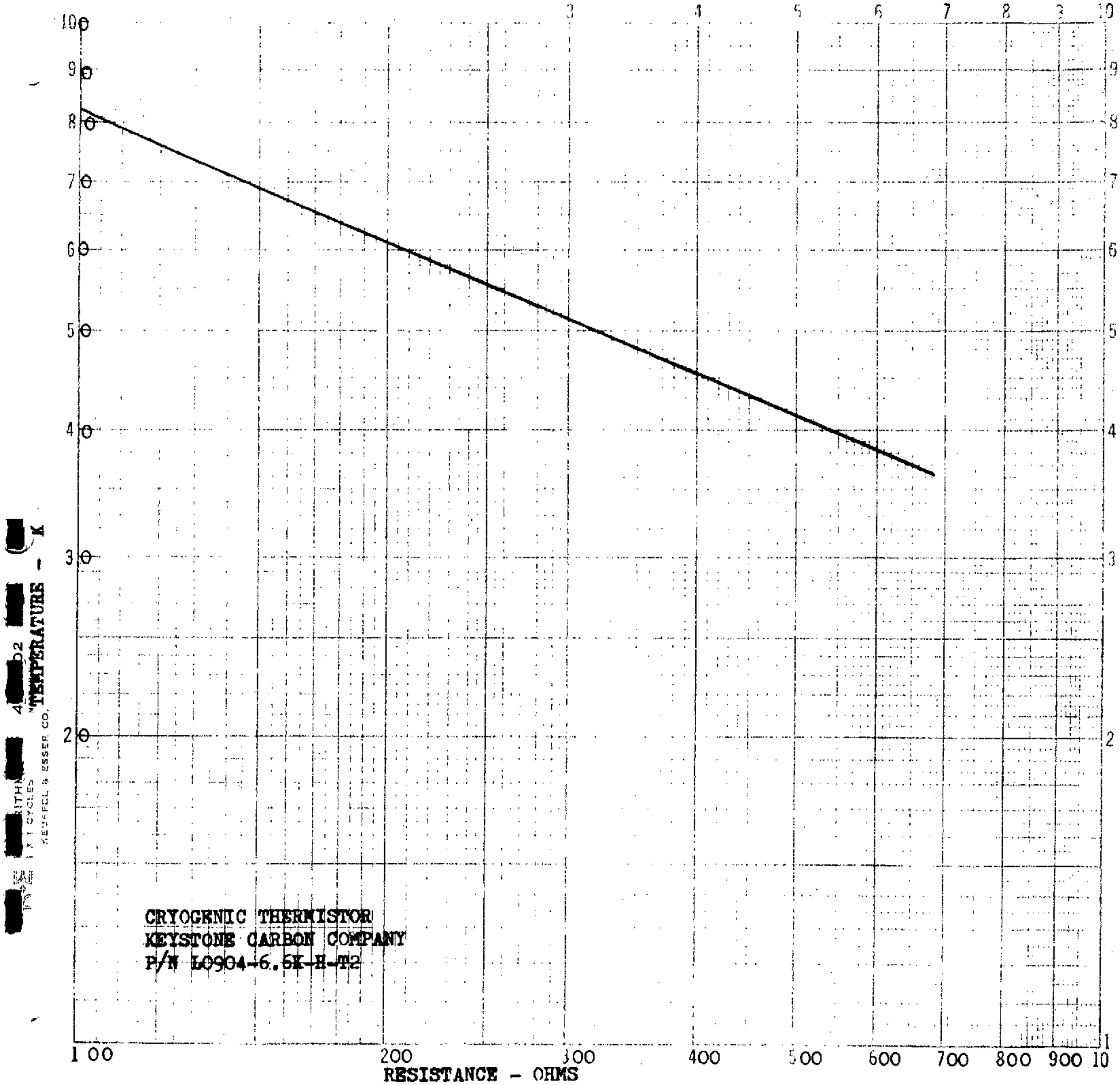
The temperature monitor incorporates a meter driver circuit and an adjustable input bridge similar to the control bridge. The thermistors used for control and monitor functions have been calibrated by the manufacturer at 90^{o}, $77^{o}K$ and $20.25^{o}K$. From this data the approximate temperature coefficients have been determined and the temperature/resistance curves have been plotted. These plots are included in Appendix A. It should be noted that these cruves do not represent true calibrations except at the points noted. However, the optimum detector operating points have been established using these curves and thus, the control points can be accurately duplicated. Establishment of control can be noted on the control indicator meter and the approximate operating temperature can be determined from the temperature monitor meter.

APPENDIX C(A)

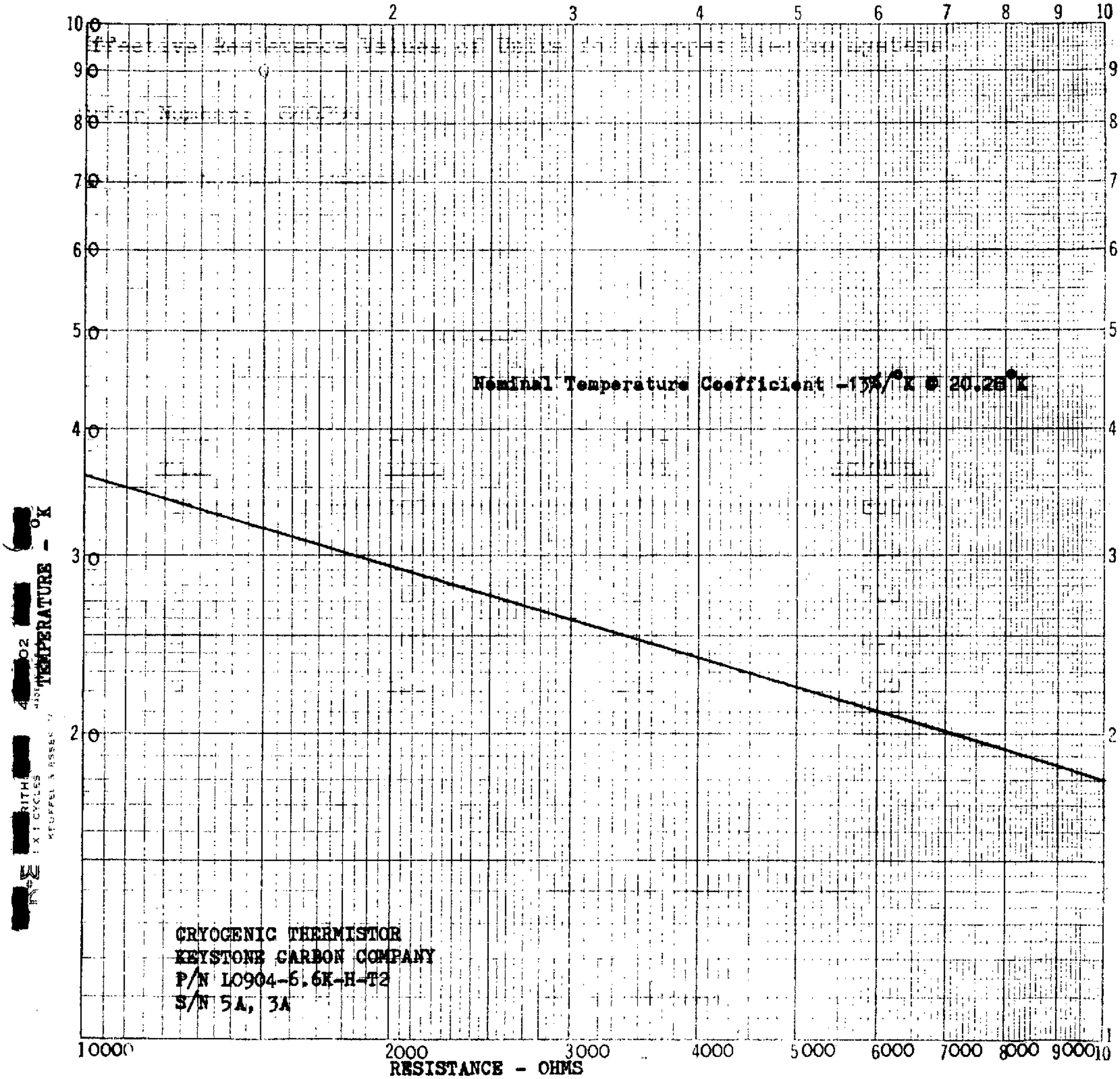
Thermistor Calibrations



THERMISTOR CALIBRATION - **Array 3** Monitor



THERMISTOR CALIBRATION - ARRAY 3 CONTROL



THERMISTOR CALIBRATION - ARRAY 4 CONTROL & MONITOR THERMISTOR

APPENDIX C(B)

Acceptance Test Data Sheets

CHARACTERISTIC	SPEC. PARAGRAPH	CHANNEL	D^* SPECIFIED	CORRESPONDING S/N REQUIRED	MEASURED SIGNAL	MEASURED NOISE	MEASURED S/N	ACTUAL D^*	DETECTOR TEMP °K
A. Detectivity $D^*(\lambda, 1000, 1)$ $\frac{cm \sqrt{Hz}}{W}$	4.4.3.a	13	3×10^{11}	175	51 (mv)	.175 (mv)	291	4.99×10^{11}	60°K
		14	3×10^{11}	4475	70.5	.065	1084	7.25×10^{10}	60°K
Test Conditions: 500°K Blackbody; 0.2 in. Aperture; 1000 Hz Chopper; 6 Hz Bandwidth; 14.38 in. (detector to aperture)		15	3×10^{11}	2145	400	.37	1081	1.51×10^{11}	60°K
		16	4×10^{10}	1958	1700	.60	2833	5.81×10^{10}	28°K
		17	4×10^{10}	489	670	70	957	7.83×10^{10}	
		18	4×10^{10}	457	580	.58	1000	8.75×10^{10}	
		19	4×10^{10}	419	780	.81	962	9.21×10^{10}	
		20	4×10^{10}	783	670	.60	1116	5.71×10^{10}	
		21	4×10^{10}	640	710	.69	1028	6.44×10^{10}	
		22	4.5×10^{10}	484	550	.68	808	7.54×10^{10}	28°K

CHARACTERISTIC	SPEC. PARAGRAPH	CHANNEL	Requirement	100 Hz	200 Hz	500 Hz	1 KHz	2 KHz	5 KHz	10 KHz	20 KHz	50 KHz	100 KHz	200 KHz
B. Responsivity vs Frequency	4.4.3.b	13	.1 - 200 KHz all Channels ± 1.0 db	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2.8
		14		-2	-2	-2	-2	-2	-1.9	-1.9	-1.7	-1.2	-1.6	-4.3
		15		-2	-2	-2	-2	-2	-2	-2.1	-2.1	-2.1	-2.4	-5.6
		16		-2	-2.1	-2.1	-2.1	-2.1	-2.5	-2.5	-2.3	-1.7	-2.2	-4.3
		17		-2	-2	-2.1	-2.1	-2.2	-2.2	-2.7	-2.7	-1.9	-2	-3.6
		18		-1.9	-2	-2	-2.1	-2.1	-2.4	-2.3	-1.6	-1.6	-2.1	-3.6
		19		-1.8	-2	-2.1	-2.1	-2.2	-2.5	-2.2	-1.7	- .9	-1.2	-2.8
		20		-2	-2	-2	-2.1	-2.1	-3.0	-3.2	-2.4	-1.7	-1.7	-3.2
		21		-1.7	-1.9	-1.9	-1.9	-2	-2	-2.3	-2.5	-2.9	-3.5	-4.4
		22		-2	-2	-2.1	-2.1	-2.2	-2.1	-2.3	-2.3	-2.3	-2.2	-3.0

CHARACTERISTIC	SPEC. PARAGRAPH	CHANNEL	CENTER WAVELENGTH NOMINAL	CENTER WAVELENGTH ACTUAL	LOWER 50% TRANSMISSION NOMINAL	LOWER 50% TRANSMISSION ACTUAL	UPPER 50% TRANSMISSION NOMINAL	UPPER 50% TRANSMISSION ACTUAL
C. Spectral Response	4.4.3.c	13	2.23		2.10		2.36	
		14	3.77		3.54		4.00	
		15	4.63		4.50		4.75	
		16	6.50		6.0		7.0	
		17	8.55		8.30		8.80	
		18	9.05		8.80		9.30	
		19	9.55		9.30		9.80	
		20	10.55		10.10		11.00	
		21	11.50		11.00		12.00	
		22	12.50		12.00		13.00	

CHARACTERISTIC	SPEC. PARAGRAPH	CHANNEL	MEASURED NOISE VOLTAGE (RMS)	DETECTOR TEMPERATURE
D. Wide Band Noise	4.4.3.d	13	10 MV	$60^{o}K$
		14	9.9	$60^{o}K$
		15	11.5	$60^{o}K$
		16	13.2 MV	$28^{o}K$
		17	13.6	
		18	13.8	
		19	19.4	
		20	14.1	
		21	16.3	
		22	18.7	$28^{o}K$

	CHARACTERISTIC	SPEC. PARAGRAPH	CHANNEL	CALCULATED SIGNAL (MV)	MEASURED SIGNAL
E.	Detector, Amplifier Responsivity - Output Signal Level	4.4.3.e	13	-	51 (mv)
			14	-	70.5
			15	-	400
					DEMONSTRATED
			16	175	✓
			17	77	✓
			18	66	✓
			19	83	✓
			20	67	✓
			21	76	✓
			22	58	✓
F.	Zero Restore Performance	4.4.3.f	Selected	Specification $\leq$ 1% droop in 100 ms	✓
G.	Temperature Control Function	4.4.3.g	Array 3	Observe Stability on Control Meter	✓
			Array 4	Observe Stability on Control Meter	✓
	Temperature Monitor Function	4.4.3.k	Array 3	Observe Temperature on Monitor Meter	✓
			Array 4	Observe Temperature on Monitor Meter	✓

APPENDIX C(C)

Window Transmission Plots

Detector Spectral Response Plots

Filter Spectral Transmission Plots

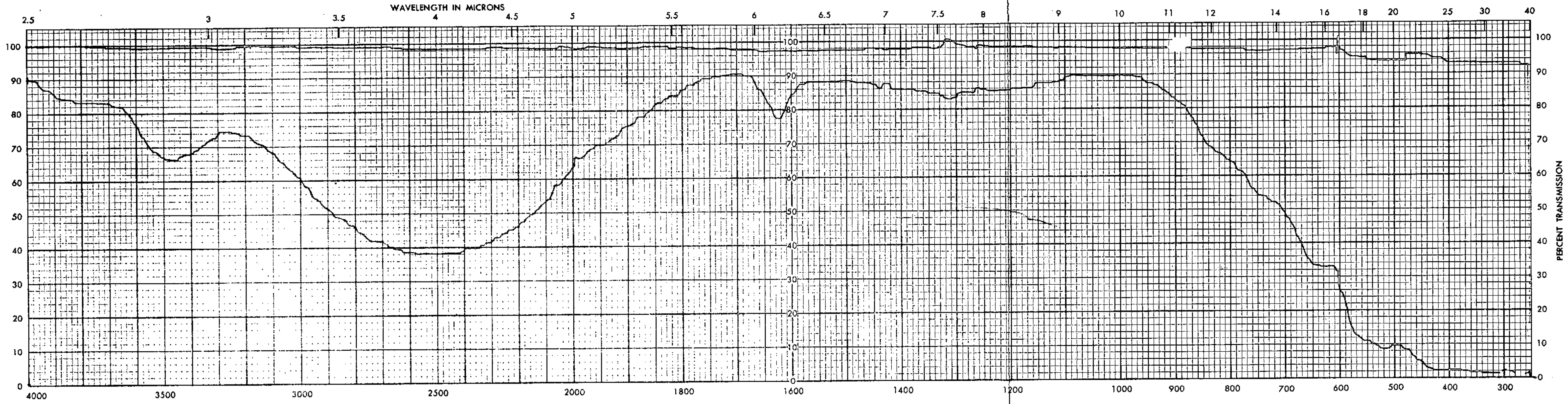
FOLDOUT FRAME 1

FOLDOUT FRAME 2

FOLDOUT FRAME 3

SPECTRUM NO.
DATE July 10th 72
SAMPLE Ge
SOURCE IR 20A
STRUCTURE
NASA Array 4
NAS 9-12199
PATH ___ mm
SOLVENT
CONCENTRATION
PHASE
COMMENTS
W.O. 1766-01-0440
ANALYST B. H.

Beckman® INFRARED SPECTROPHOTOMETER



ARRAY 4 GERMANIUM WINDOW TRANSMISSION

FOLDOUT FRAME 1

FOLDOUT FRAME 2

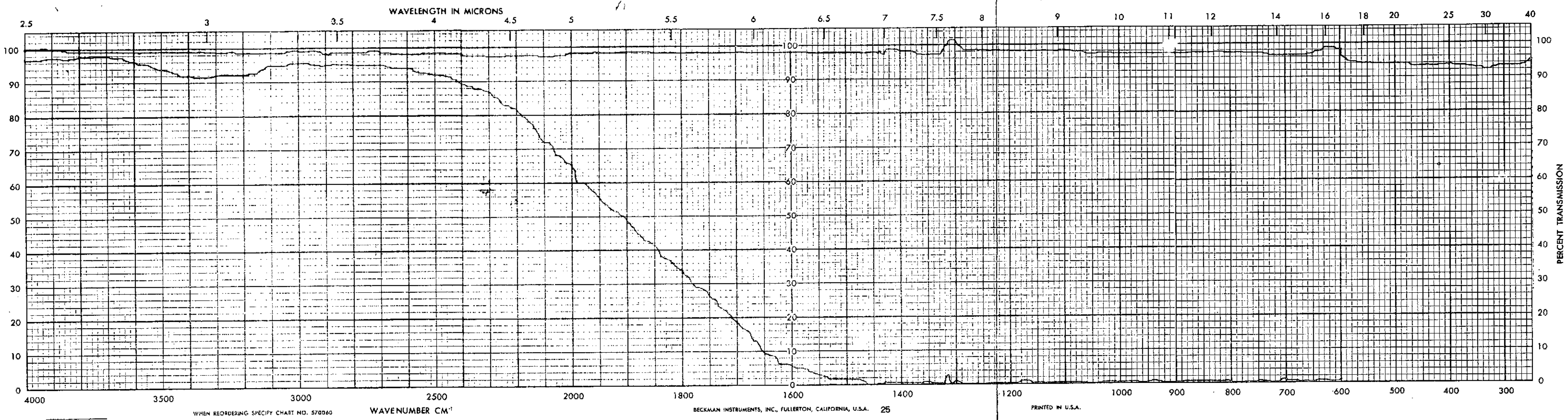
FOLDOUT FRAME 3

SPECTRUM NO.
DATE July 10th 72
SAMPLE Sapphire

SOURCE IR-20A
STRUCTURE
NAIM ARRAY 3
NAS 9-13189
PATH mm
SOLVENT
CONCENTRATION
PHASE
COMMENTS

W.O. 1766-01-0430
ANALYST B.H.

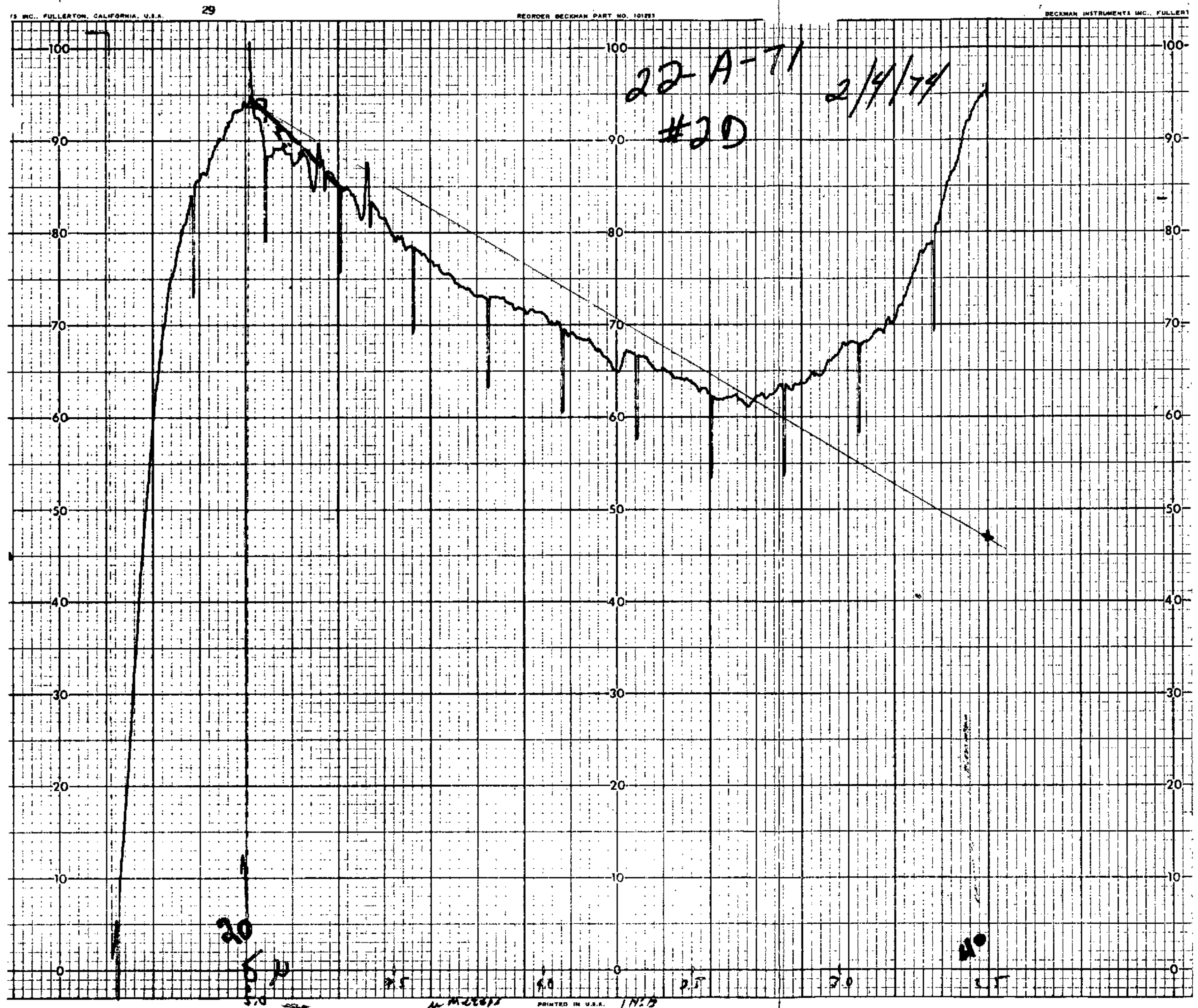
Beckman®
INFRARED SPECTROPHOTOMETER



ARRAY 3 SAPPHIRE WINDOW TRANSMISSION

FOLDOUT FRAME 1

FOLDOUT FRAME 2

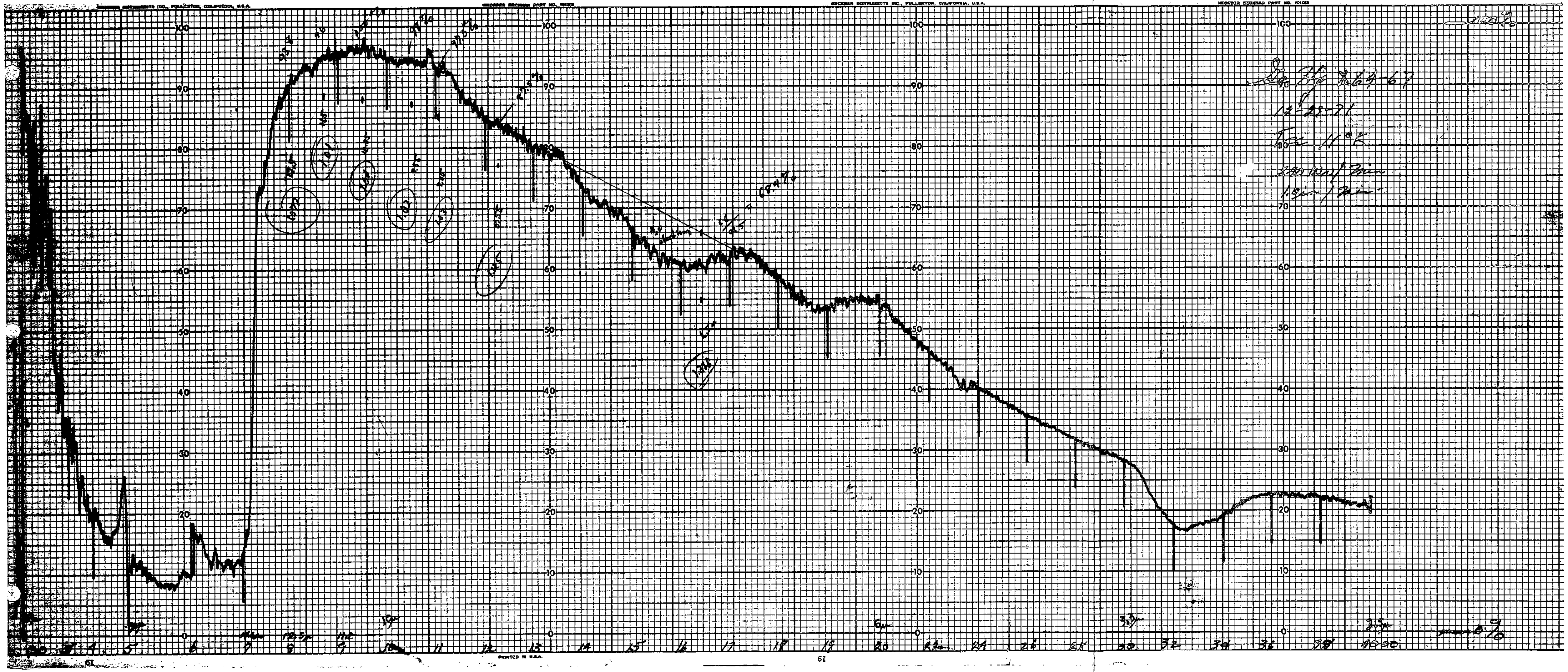


ARRAY 3 INDIUM ANTIMONIDE SPECTRAL RESPONSE

FOLDOUT FRAME 1

FOLDOUT FRAME 2

FOLDOUT FRAME 3



ARRAY 4 GE:HG DETECTOR SPECTRAL RESPONSE

OCLI OPTICAL COATING LABORATORY, INC.

2789 Giffen Avenue
Santa Rosa, California
Telephone (707) 545-6440

SPECTRAL PERFORMANCE

DATA IDENTIFICATION

OCLI W/O 14-4635-760
Run No. 5-5-9-561-099
5-5-9-561-100

Serial No. CHANNEL No. 13

SAMPLE IDENTIFICATION

Filter Type BP
Material VYCOR

Configuration 0.040"

INST. OPERATING PARAMETERS

- ☐ CARY 90
- ☐ CARY 14
- ☐ PE 180
- ☐ IR-12
- ☑ IR-4
- ☐

Resolution 1.5X STD SLIT
Scan Speed 0.20μ/min
Response INF.
Aperture SEE BELOW
Expansion 0 TO 100%

- ☑ Percent Transmission
- ☐ Percent Reflection
- ☐

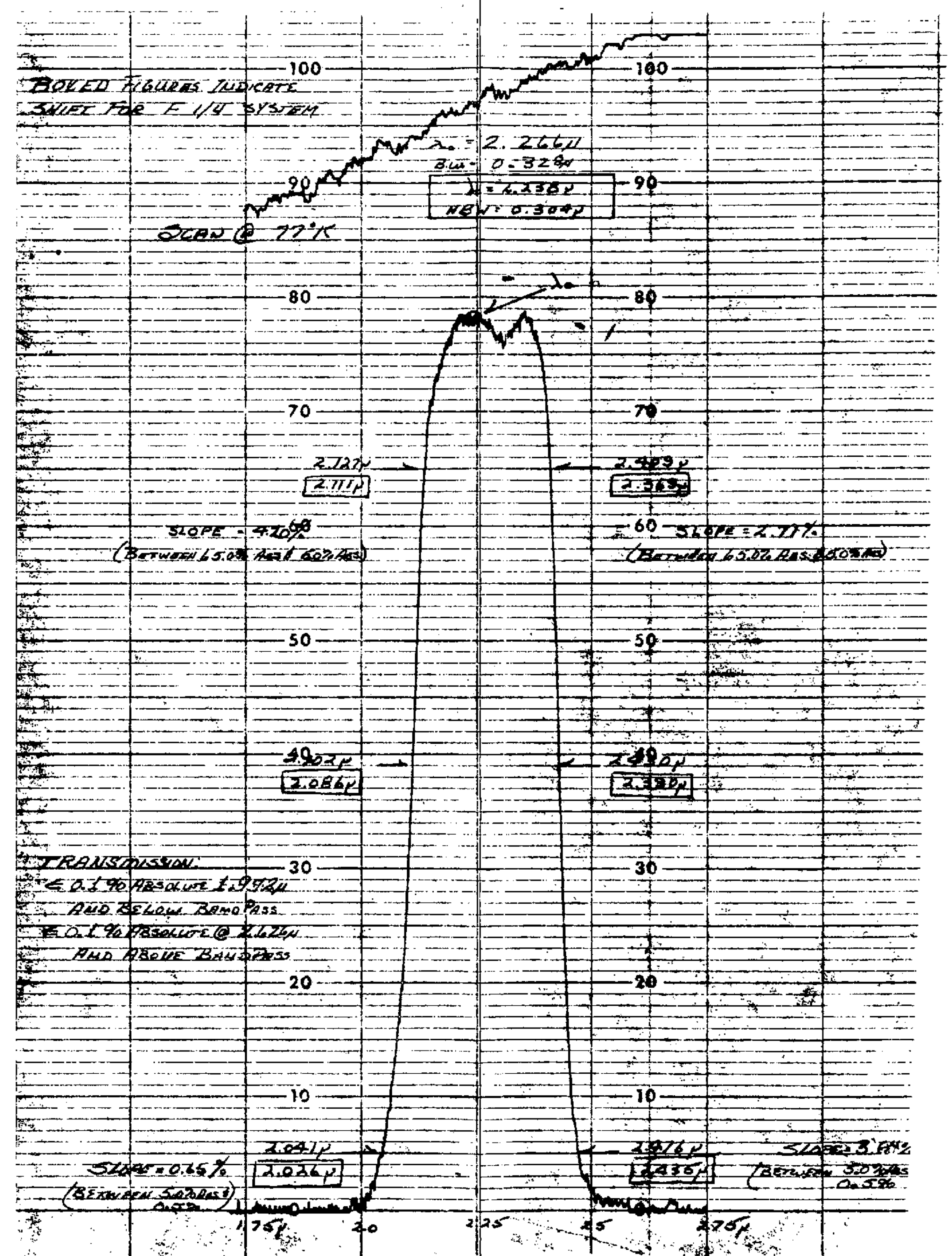
TEST CONDITIONS

Temp. AS NOTED Angle 0°
SCANNED IN CRYOSTAT WITH CAF2 WINDOWS.

Analyst [illegible] Date 5-10-75

PAGE ..... of .....

- ☐ Wavenumber
- ☑ Wavelength in μ's



Channel 13 Filter Transmission

FOLDOUT FRAME 1

FOLDOUT FRAME 2

FOLDOUT FRAME 3

OCLI OPTICAL COATING LABORATORY, INC.
2789 Giffen Avenue
Santa Rosa, California
Telephone (707) 545-6440

SPECTRAL PERFORMANCE

DATA IDENTIFICATION

OCLI W/O 14-4639-760
Run No. SS-2-561-090
SS-3-561-092

Serial No. #14 - CHANNEL ARRAY 3 Nos 1 & 2 (SETS)

SAMPLE IDENTIFICATION

Filter Type BAND PASS
Material Sapphire
Configuration 1.0" dia 0.040" THK

INST. OPERATING PARAMETERS

- [x] CARY 90
- [ ] CARY 14
- [ ] PE 180
- [ ] IR-12
- [ ] IR-4

Resolution Slit 1.05 cm⁻¹
Scan Speed 0.35 cm⁻¹/sec
Response 0.3
Aperture CRYOSTAT
Expansion 0 TO 100%

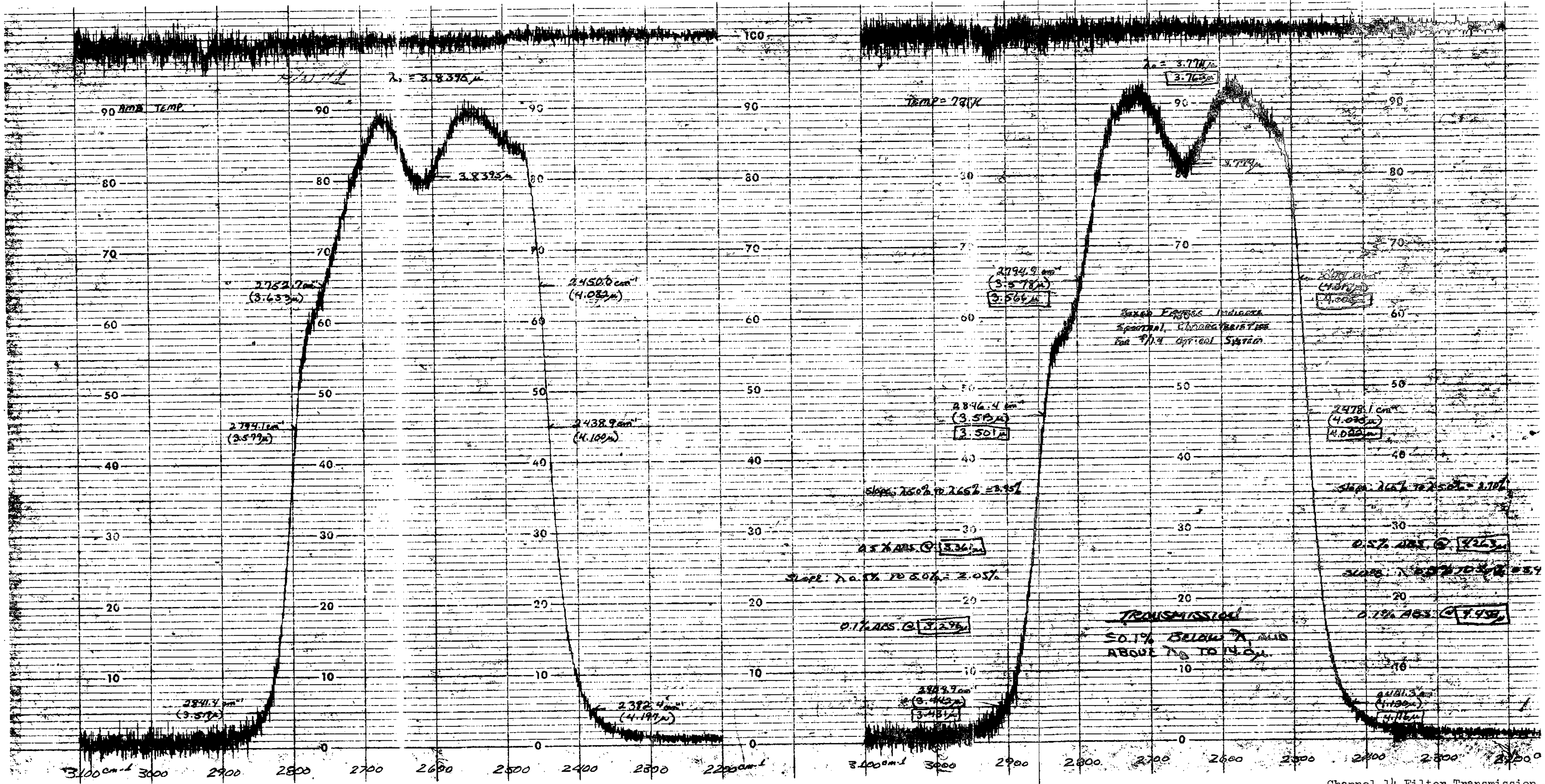
- [x] Percent Transmission
- [ ] Percent Reflection

TEST CONDITIONS

Temp. AS NOTED Angle 0°
CaF2 WINDOWS

Analyst MEJ-34 Date 5-7-73

- [x] Wavenumber
- [ ] Wavelength in



Channel 14 Filter Transmission

FOLDOUT FRAME 1

FOLDOUT FRAME 2

OCLI OPTICAL COATING LABORATORY, INC.

2789 Giffen Avenue
Santa Rosa, California
Telephone (707) 545-6440

SPECTRAL PERFORMANCE

DATA IDENTIFICATION

OCLI W/O 14- 4639-760
Run No. 5-5-8-561-096

Serial No. CHANNEL #15 ARRAY-3 S/N's 1 & 2 (SETS)

SAMPLE IDENTIFICATION

Filter Type BAND PASS
Material SAPPHIRE

Configuration 1.0" dia 0.040" THK

INST. OPERATING PARAMETERS

☒ CARY 90 ☐ IR-12
☐ CARY 14 ☐ IR-4
☐ PE 180 ☐

Resolution Slit 1.25 cm⁻¹
Scan Speed 0.2 cm⁻¹/sec
Response 0.3
Aperture CRYOSTAT
Expansion 0 TO 100%

☒ Percent Transmission
☐ Percent Reflection
☐

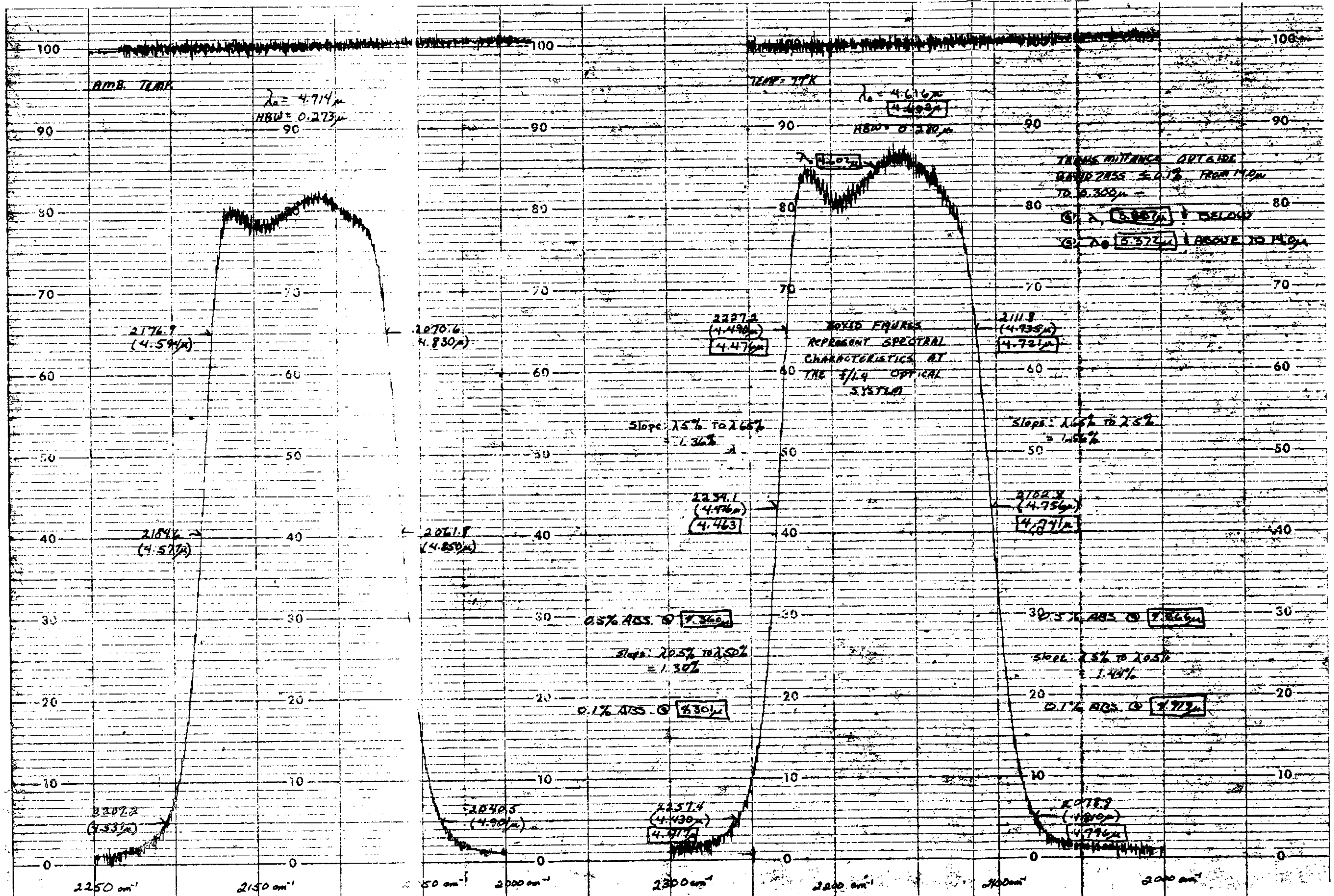
TEST CONDITIONS

Temp. AS NOTED Angle 0°

Analyst G.J. - J.P. Date 5-8-73

PAGE .... of ....

☒ Wavenumber
☐ Wavelength in



Channel 15 Filter Transmission

FOLDOUT FRAME 1

FOLDOUT FRAME 2

FOLDOUT FRAME 3

OCLI OPTICAL COATING LABORATORY, INC.

2789 Giffen Avenue
Santa Rosa, California
Telephone (707) 545-6440

SPECTRAL PERFORMANCE

DATA IDENTIFICATION

OCLI W/O 14-4639-760
Run No. 5515 541-193,194 B

Serial No. CHANNEL 16

SAMPLE IDENTIFICATION

Filter Type WBP
Material GERMANIUM

Configuration 1" X 0.040"

INST. OPERATING PARAMETERS

☒ CARY 90 (5-25) ☐ IR-12
☐ CARY 14 ☐ IR-4
☐ PE 180 ☐

Resolution 2.5cm⁻¹ SLIT
Scan Speed 2cm⁻¹/SEC
Response 1
Aperture 0.7
Expansion 0-100

☒ Percent Transmission
☐ Percent Reflection
☐

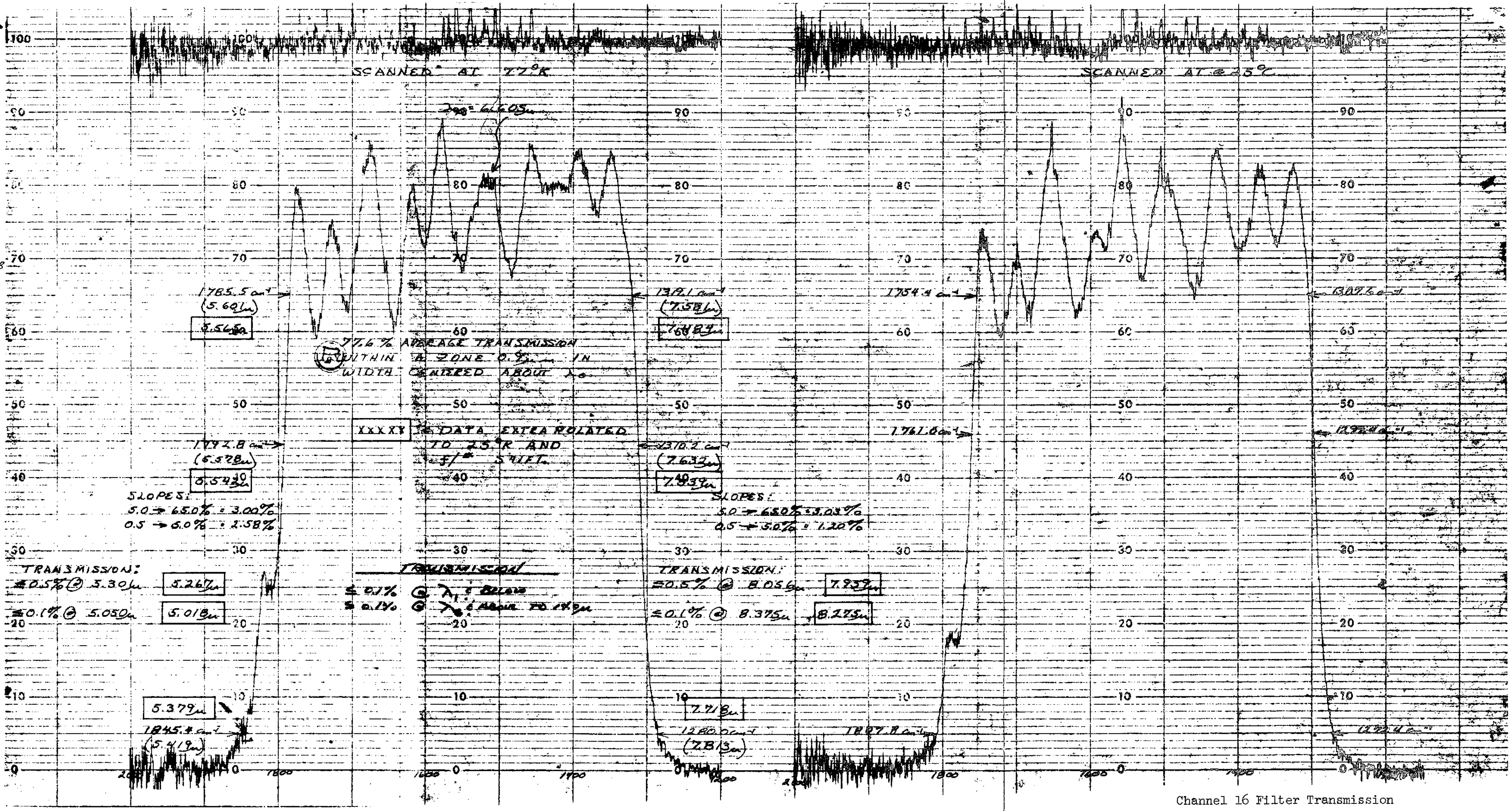
TEST CONDITIONS

Temp. AS NOTED Angle 0°
CRYOSTAT WITH
CSI WINDOWS

Analyst YG Date 5-7-73

PAGE .... of ....

☒ Wavenumber
☐ Wavelength in cm⁻¹



Channel 16 Filter Transmission

OCLI OPTICAL COATING LABORATORY, INC.

2789 Giffen Avenue
Santa Rosa, California
Telephone (707) 545-6440

SPECTRAL PERFORMANCE

DATA IDENTIFICATION

OCLI W/O 14-4637
Run No.
Serial No. ARRAY-4
SETS 1 & 2

SAMPLE IDENTIFICATION

Filter Type
Material

Configuration

INST. OPERATING PARAMETERS

☒ CARY 90 ☐ IR-12
☐ CARY 14 ☐ IR-4
☐ PE 180 ☐

Resolution
Scan Speed
Response
Aperture
Expansion

☒ Percent Transmission
☐ Percent Reflection
☐

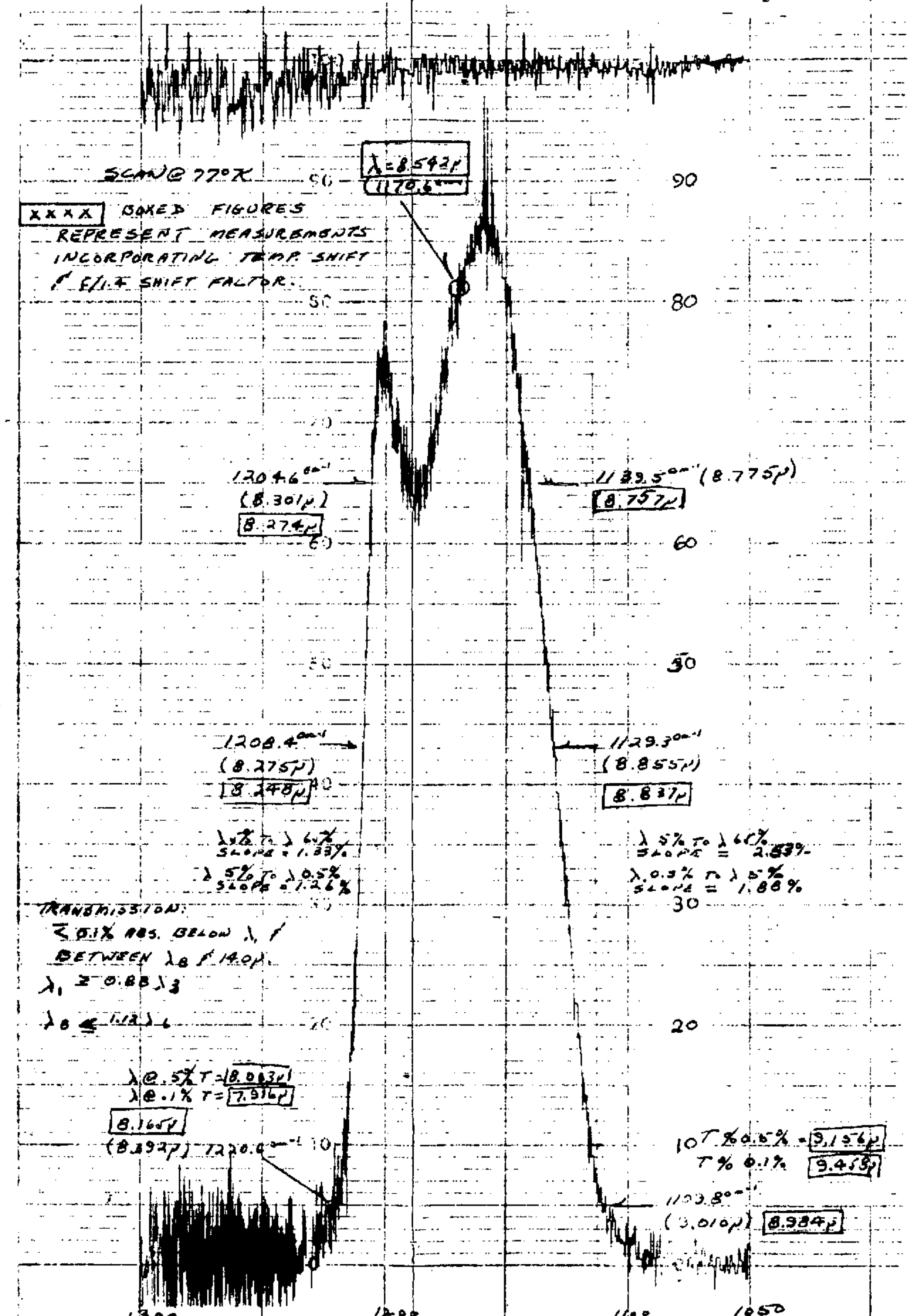
TEST CONDITIONS

Temp. Angle 0°

Analyst Date

PAGE of

☒ Wavenumber
☐ Wavelength in



Channel 17 Filter Transmission

OCLI OPTICAL COATING LABORATORY, INC.

2789 Giffen Avenue
Santa Rosa, California
Telephone (707) 545-6440

SPECTRAL PERFORMANCE

DATA IDENTIFICATION

OCLI W/O 14-4639-760
Run No. 5517-542-083
CHANNEL 18
Serial No.

SAMPLE IDENTIFICATION

Filter Type BANDPASS
Material GERMANIUM
Configuration 0.040"

INST. OPERATING PARAMETERS

☒ CARY 90 ☐ IR-12
☐ CARY 14 ☐ IR-4
☐ PE 180 ☐

Resolution SLIT: 1.5 cm⁻¹
Scan Speed 0.3 cm⁻¹/SEC
Response 1
Aperture CRYOSTAT W/CSI WINDOWS
Expansion 0 TO 100.0

☒ Percent Transmission
☐ Percent Reflection
☐

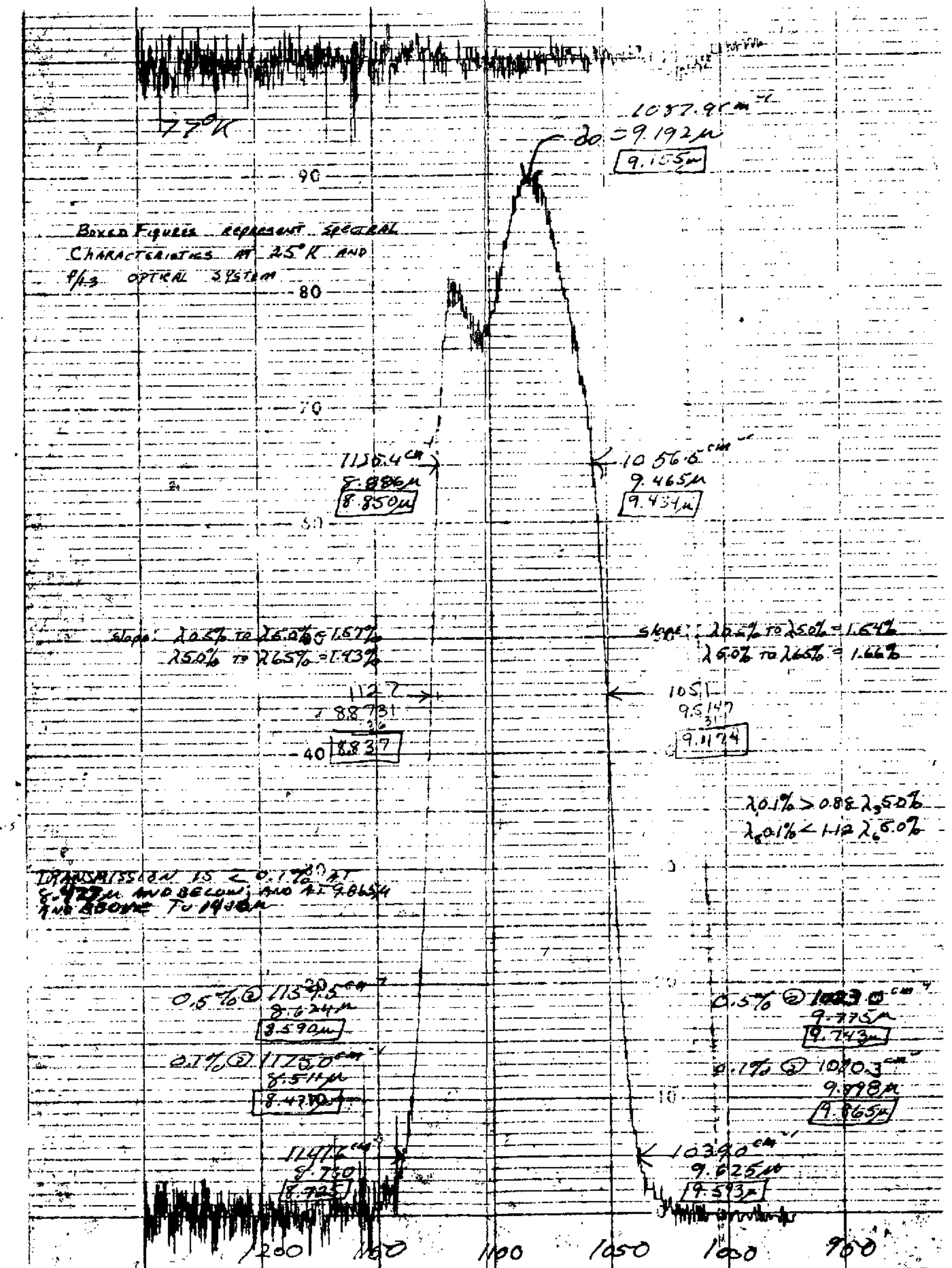
TEST CONDITIONS

Temp. AS NOTED Angle: 0°

Analyst JRC Date 5/18/73

PAGE ... of ...

☒ Wavenumber
☐ Wavelength in ...



Channel 18 Filter Transmission

OCLI OPTICAL COATING LABORATORY, INC.

2739 Giffen Avenue
Santa Rosa, California
Telephone (707) 545-6440

SPECTRAL PERFORMANCE

DATA IDENTIFICATION

OCLI W/O 4-4639-760
Run No. 5522-542-686
CHANNEL 19
Serial No.

SAMPLE IDENTIFICATION

Filter Type BANDPASS
Material GERMANIUM

Configuration 5060

INST. OPERATING PARAMETERS

- [x] CARY 90
- [ ] CARY 14
- [ ] PE 180
- [ ] IR-12
- [ ] IR-4
- [ ]

Resolution SLIT: 2 cm⁻¹
Scan Speed 0.5 cm⁻¹/SEC
Response 1
Aperture CRYOSTAT w/ KBr WINDOWS
Expansion 0 TO 100

- [x] Percent Transmission
- [ ] Percent Reflection
- [ ]

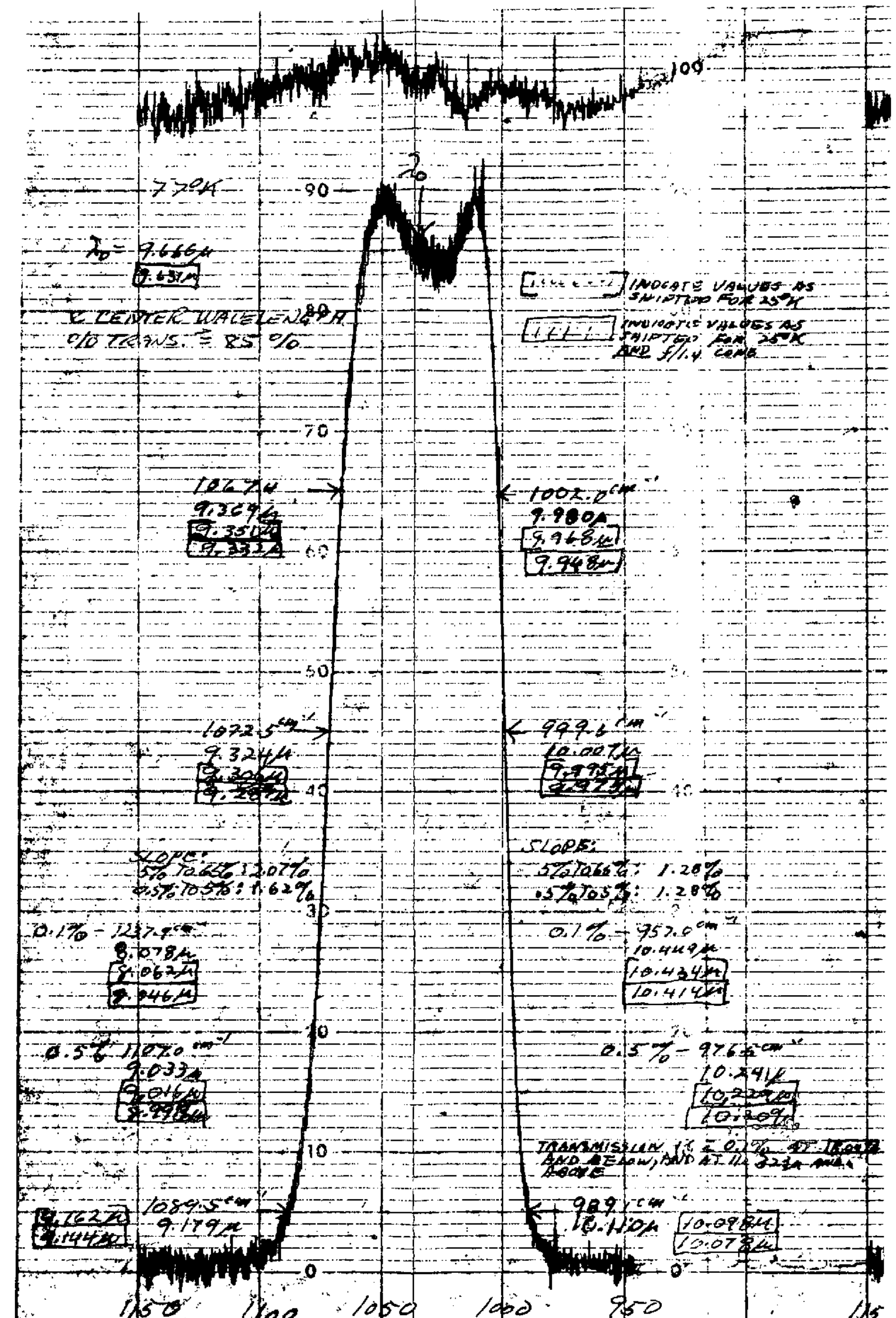
TEST CONDITIONS

Temp. As NOTED Angle 0°

Analyst [illegible] Date 5/23/74

PAGE ... of ...

- [x] Wavenumber
- [ ] Wavelength in ...



Channel 19 Filter Transmission

FOLDOUT FRAME

CLI OPTICAL COATING LABORATORY, INC.
2789 Giffen Avenue
Santa Rosa, California
Telephone (707) 545-6440

ECTRAL PERFORMANCE

DATA IDENTIFICATION

W/O 14-4639-265
No. 5524-542-587

CHANNEL #20
ARRAY-4
SETS 1 & 2

SAMPLE IDENTIFICATION

Type BANDPASS
Material GERMANIUM

Configuration 1" X .040"

INST. OPERATING PARAMETERS

- [x] CARY 90 S-37
- [ ] IR-12
- [ ] CARY 14
- [ ] IR-4
- [ ] PE 180

Resolution 2 cm⁻¹ SLIT
Scan Speed 0.5 cm⁻¹/SEC.
Response 1
Aperture 0.2"
Expansion 0-100

- [x] Percent Transmission
- [ ] Percent Reflection

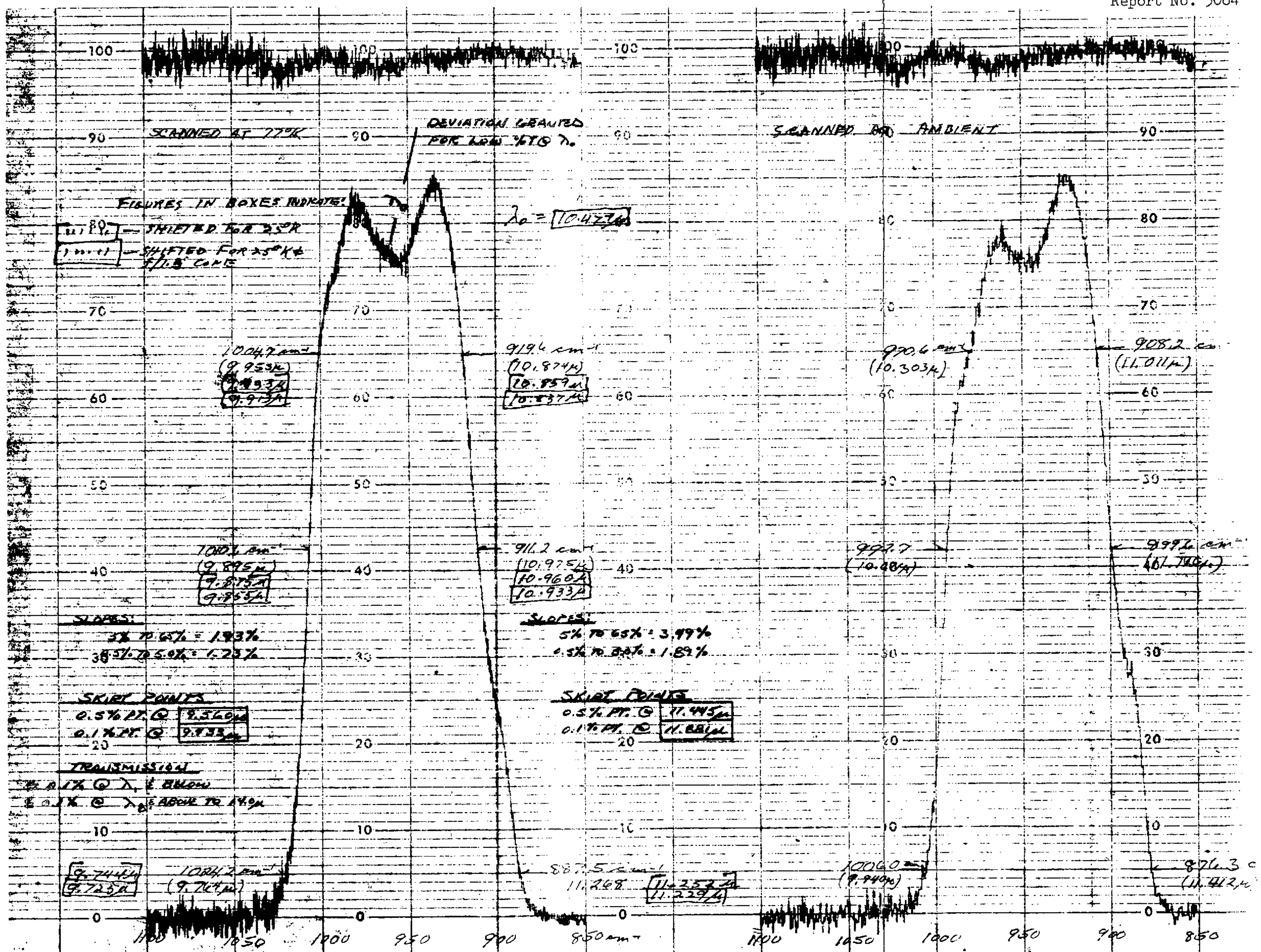
TEST CONDITIONS

Temp. AS NOTED Angle
CRYOSTAT
KBr WINDOWS

Analyst Date

PAGE of

- [x] Wavenumber
- [ ] Wavelength in cm⁻¹



Channel 20 Filter Transmission

FOLDOUT FRAME

FOLDOUT FRAME

OCLI OPTICAL COATING LABORATORY, INC.
2789 Giffen Avenue
Santa Rosa, California
Telephone (707) 545-6440

SPECTRAL PERFORMANCE

DATA IDENTIFICATION

OCLI W/O 14-4639-240
Run No. 552-542-070
553-542-071
554-542-072
Serial No. CHANNEL #21 ARRAY-4 (SETS)

SAMPLE IDENTIFICATION

Filter Type BANDPASS
Material GERMANIUM
Configuration 1" X 0.040" PART

INST. OPERATING PARAMETERS

☒ CARY 90 ☐ IR-12
☐ CARY 14 ☐ IR-4
☐ PE 180 ☐

Resolution
Scan Speed
Response 0.3
Aperture
Expansion 0-100

☒ Percent Transmission
☐ Percent Reflection
☐

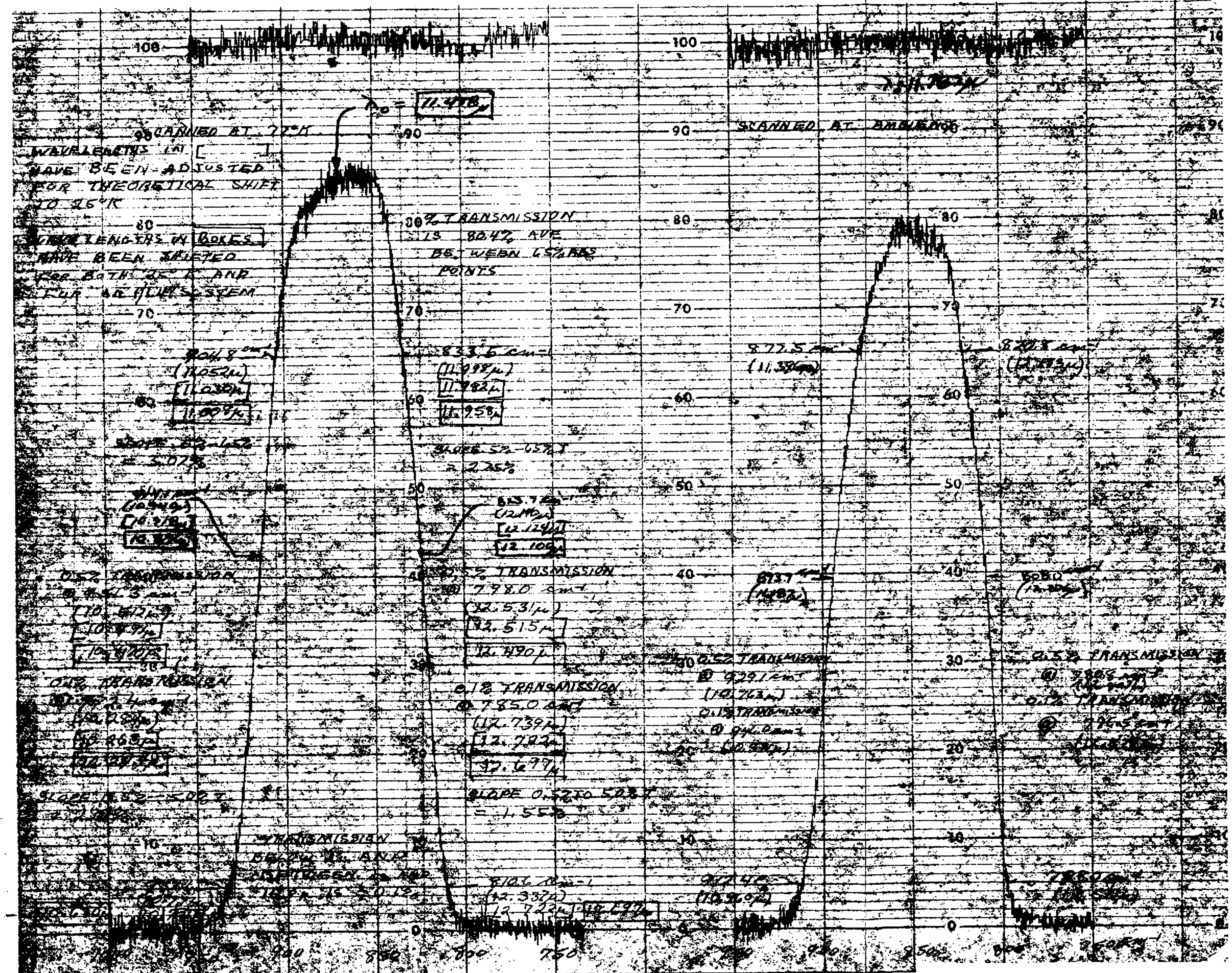
TEST CONDITIONS

Temp. AS NOTED Angle 0°
CRYOSTAT WITH CSI WINDOWS

Analyst Date 5-2-73

PAGE of

☒ Wavenumber
☐ Wavelength in



Channel 21 Filter Transmission

OCLI OPTICAL COATING LABORATORY, INC.

2789 Giffen Avenue
Santa Rosa, California
Telephone (707) 545-6440

SPECTRAL PERFORMANCE

DATA IDENTIFICATION

OCLI W/O 14-4639-760
Run No. 559-542-075
Serial No. CHANNEL 22

SAMPLE IDENTIFICATION

Filter Type BAND PASS
Material GERMANIUM
Configuration 0.040"

INST. OPERATING PARAMETERS

☒ CARY 90 ☐ IR-12
☐ CARY 14 ☐ IR-4
☐ PE 180 ☐

Resolution SLIT: 1 ...
Scan Speed 0.7 cm/sec
Response 0.3
Aperture CRYOSTAT CSI ...
Expansion 0 TO 100 %

☒ Percent Transmission
☐ Percent Reflection
☐

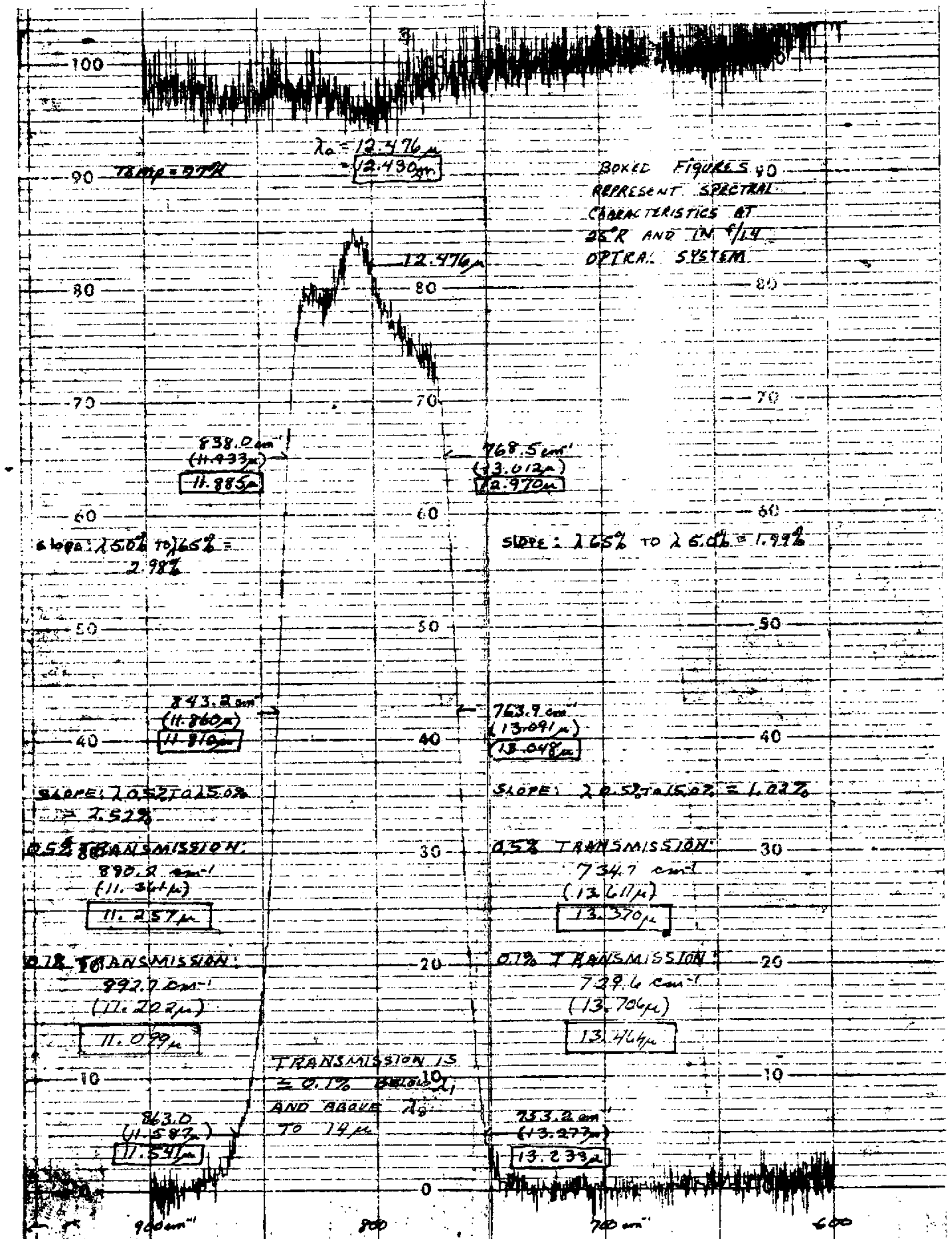
TEST CONDITIONS

Temp. As NOTED Angle 0°

Analyst g.y. Date 5/10/73

PAGE ... of ...

☒ Wavenumber
☐ Wavelength in ...



Channel 22 Filter Transmission